SMITHSONIAN

MISCELLANEOUS COLLECTIONS

VOL. 99

" EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN "—SMITHSON

ADVERTISEMENT

The Smithsonian Miscellaneous Collections series contains, since the suspension in 1916 of the Smithsonian Contributions to Knowledge, all the publications of the Institution except the Annual Report, the annual pamphlet describing the Institution's field-work, and occasional publications of a special nature. As the name of the series implies, its scope is not limited, and the volumes thus far issued relate to nearly every branch of science. Papers in the fields of biology, geology, anthropology, and astrophysics have predominated.

<div align="right">

C. G. ABBOT,
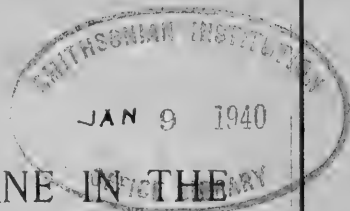*Secretary of the Smithsonian Institution.*

</div>

CONTENTS

SKETCHES BY PAUL KANE IN THE INDIAN COUNTRY, 1845-1848

BY
DAVID I. BUSHNELL, JR.

(PUBLICATION 3553)

Paul Kane,

SKETCHES BY PAUL KANE IN THE INDIAN COUNTRY, 1845-1848

BY
DAVID I. BUSHNELL, JR.

SKETCHES BY PAUL KANE IN THE INDIAN COUNTRY, 1845-1848

By DAVID I. BUSHNELL, Jr.

Paul Kane was born September 3, 1810. Some accounts assert that he was a native of Mallow, County Cork, Ireland; others say he was born in Canada after his parents had arrived in their new home. However that may be, the date is not questioned. He died at his home in Toronto, February 20, 1871. A notice in the Toronto Globe, 2 days after his death, referred to him as "an old resident of the city of Toronto, and one of our pioneers."

Where or under whom Kane may have studied drawing or painting is not known, but it is thought he painted in Toronto and Cobourg until the year 1835, and about that time came to the United States, where he remained 5 or 6 years. Thence he went to Europe and studied in England and on the continent, and returned to Toronto early in 1845. Soon after his return from Europe, later in the same year, he again continued his wanderings, this time into the Indian country to the westward. Kane's only publication, "Wanderings of an Artist among the Indians of North America," is a record of his travels among the Indians and was published in London, England, 1859. It is a work of much interest. Another book was contemplated, but failing eyesight made it impossible for him to continue writing and painting.

A century ago many Indians were to have been encountered in the vicinity of Toronto, with native camps and villages on the shores of lakes and streams to the northward. Georgian Bay, that great arm of Lake Huron, with its innumerable islands, was bordered by the camps of several tribes who were attracted to the region to hunt and fish. Toronto, the seat of government, was often visited by groups of Indians who came to treat with the Indian agent, and during the long winters was frequented by others who sought aid when food became scarce and wild game could not be procured. Such were the surroundings and conditions which early caused the young artist to become interested in the Indians, an interest which developed and later impelled him to undertake two long journeys into the wilderness for the purpose of obtaining a series of authentic sketches of the natives in their natural environments. To quote from the preface of his "Wanderings": "The principal object in my

undertaking was to sketch pictures of the principal chiefs, and their original costumes, to illustrate their manners and customs, and to represent the scenery of an almost unknown country." How very successful he was in his endeavors will be shown in the following pages.

The first and shorter of Kane's two important trips was made during the year 1845. He left Toronto June 17, and after an absence of 5½ months returned home on the first day of December. On May 9, 1846, he started on his more important journey, which led him across the continent. He arrived at Fort Vancouver December 8, 1846, and continued on to Fort Victoria. Two years later, during October 1848, he returned safely to Toronto bearing with him a rich collection of "pictures of the principal chiefs, and their original costumes," also sketches of the country through which he had passed, and of scenes which he had witnessed. But he did not keep a journal during his wanderings, and consequently the volume that he later published is thought to have been compiled from memory, with the aid of scant notes which he may have had but of which no record has been preserved. "Wanderings" was written several years after his return to Toronto, and in preparing the manuscript he is believed by some to have been assisted by one of the scholars of the day, one who was then connected with the University of Toronto.

The sketches made by Kane during his second trip attracted many persons to his work, and when exhibited they received much favorable comment and created great interest. He had been assisted on his journey to the Pacific by Sir George Simpson, from whom he received letters to the Factors of all posts of the Hudson's Bay Company. Later he painted 12 pictures in oil for Simpson, and also the same number for the Government. Regarding these Dr. Kenney writes:

> The twelve pictures painted for Sir George Simpson which, it is quite possible, were the same as the twelve that were exhibited in Buckingham Palace, London, in 1858, have, apparently, disappeared. Of the twelve that were painted for the Parliament of Canada, six are in the National Gallery, Ottawa; five are in the chambers of the Speaker of the House of Commons, Ottawa, and one is lost, possibly burned.[1]

As related to the writer by Mrs. Maude Allan Cassels, at her home in Toronto, during the summer of 1931, her father, the late Hon. George W. Allan, did not meet Kane until after the latter returned from the Pacific. About the close of 1852 they again met, and Kane

---

[1] Quoted from a personal letter from Dr. J. F. Kenney, Public Archives of Canada, June 8, 1939.

was in despair because, after much petitioning and long waiting, the Government would only give him an order for 12 pictures for which he was to receive £500. The amount was not enough to enable him to do what he desired—write and publish his book. Then it was that her father gave Kane the order for 100 paintings, for which he paid at the same rate as the Government had paid for the 12. The paintings remained in the family for many years—until the unique collection was acquired by Dr. E. B. Osler and by him presented to the Royal Ontario Museum of Archaeology, Toronto, where they are now preserved.

A large number of the artist's field sketches, made on his two trips into the Indian country, were likewise preserved in Toronto. Some were in oil, others in water color, and the great majority in pencil. These included the 1 in oil and 11 in water color now in the writer's collection.

The small water-color portrait-sketches made in the field portray the Indians as they were encountered by the artist, with all their wild and barbaric surroundings. The features of all are carefully drawn, but some are less finished than others, thus revealing the haste with which they were made. These were the original sketches from which the large portraits, now hanging in the Museum, were made by Kane in his Toronto studio. However, the latter were seldom exact copies as the artist evidently endeavored to make more pleasing pictures, but in so doing he lessened their value and interest both historically and ethnologically. The field sketches appearing in this paper have never before been reproduced.

The portrait of Paul Kane shown in the frontispiece is reproduced from a photograph made about 1855.

FIRST JOURNEY

June 17, 1845, to December 1, 1845

Kane departed from Toronto June 17, 1845, on the first of his two trips into the Indian country. He went without definite plans, and without a companion, and carried, so he wrote,[2] "but my portfolio and box of paints, my gun, and a stock of ammunition." He soon arrived at the south shore of Lake Simcoe, crossed to Orillia, thence continued to Sturgeon Bay on Lake Huron. Here he engaged an Indian with a bark canoe to conduct him to Penetanguishene where

---

[2] All quotations, unless otherwise stated, are from the artist's book, "Wanderings of an Artist among the Indians of North America." London, 1859.

he remained until June 20. During the next fortnight he went westward along the south shore of Georgian Bay, crossed the peninsula and visited the Ojibway village at the mouth of Saugeen River. It was an interesting settlement with a population of about 200, in the midst of rich and fertile land, only a small part of which was cultivated. Fish served as the principal article of food, but they killed "hundreds of deer by erecting a fence of brushwood many miles in extent, behind which the Indians conceal themselves; and as the deer, in their annual migrations, are seeking an opening through this fence, they fall a prey to the unerring aim of the red man."

Returning to Penetanguishene, Kane obtained necessary provisions and soon set out for Manetouawning, some 200 miles distant, in a deep bay at the extremity of Manetoulin Island, in Lake Huron. Before entering the Bay of Manetouawning he arrived at the Spider Islands, on one of which he landed to escape a heavy shower, and there remained the balance of the day sketching. A single lodge stood near the shore—"a woman and her two children were there, but the men were off in the distance fishing, which is the principal occupation of the Indians hereabouts in summer, there being very little game, except occasionally a bear or deer, and, at particular seasons, ducks."

The oil sketch, reproduced in figure 1, was made at that time and shows the single habitation mentioned in the narrative. The conical wigwam is partly covered with heavy, coarse mats and sheets of birch bark. To the right is a shelter open on one side. A fire is burning just beyond, above and in the smoke of which is a long pole from which hang what appear to be fish or bits of meat being dried.

At the time of Kane's visit the village of Manetouawning consisted of a group of 40 or 50 log cabins which had been erected for the Indians by the Provincial Government. Here was "a mission with a church and pastor, an Indian agent, a doctor, and a blacksmith, all paid by the Government." Some 2,000 Indians had gathered at the village "awaiting the arrival of the vessel that was freighted with their annual presents, comprising guns, ammunition, axes, kettles, and other implements useful to the Indian." The Indians had come from their distant camps near Lake Superior, from Nipissing, and from their villages on the islands and bordering shores of Huron.

Having remained a fortnight on Manetoulin Island, Kane continued on to Sault Ste. Marie, thence to Mackinaw. At the latter place he met Ojibway and Ottawa Indians, 2,600 in all, who had assembled

"to receive their pay of $25,000.00 for land ceded to the United States." Soon he continued his journey to Green Bay, on the west shore of Lake Michigan, and a few days after his arrival at the Bay "left in company with three gentlemen going to Fox River to see the Manomanee Indians, who were now assembling to receive their payment for lands sold to the United States Government in the vicinity of Lake Winebago."

Fig. 1.—July 1845. An Ojibway camp on one of the Spider Islands in Lake Huron, northeast of Manitoulin Island. Size, 8½ by 13 inches.

The party of four embarked in Kane's bark canoe and during the second night arrived at an Indian log cabin, on the shore of Lake Winnebago, where two Indian girls, sisters, lived. Here he remained the following day "and took their likenesses; the elder was named Iwa-toke or The Serpent, the younger was called Ke-wah-ten or The North Wind." The original portrait-sketch of Iwa-toke, the "likeness" of the narrative, in water color, is reproduced in figure 2. The most interesting detail of this sketch is the manner in which the two small braids of hair are joined on the forehead.

Leaving the cabin occupied by the sisters, the party went up Lake Winnebago to Fox River. They entered the river and stopped at "an Indian trading-house, round about which a number of idlers were pledging everything they possessed for liquor." Here, so Kane told: "an Indian called Wah-bannim, or, the White Dog, sat to me for his likeness. He was in mourning for his wife, who had died some three

months before; the mourning suit consisted of a coat of black paint
with which he had smeared his face. He apologised for not appearing
in full mourning costume to have his likeness taken, lamenting that
a part of the paint had worn off." The original water-color sketch
of the Indian, revealing the face and neck partly covered with black
paint,[3] is reproduced in figure 2. Both this and the sketch of the

FIG. 2.—Two Menominee Indians from Lake Winnebago, September 1845.
Left, girl, Iwa-toke; right, man, Wah-bannim.

girl Iwa-toke appear rather crude and unfinished when compared
with the portrait-sketches made by Kane during his return journey
from the Pacific coast to Toronto, but they are interesting examples
of his earlier work in the Indian country.

Kane reached the encampment of the Menominee Indians, where
he remained some days and then began his homeward journey. He
went by way of Fox River to Lake Winnebago. Crossing to Lake
Michigan, he embarked on a small steamer which landed him safely
at Buffalo, thence on to his home, Toronto, where he arrived December 1, 1845.

---

[3] This was an established custom and was mentioned by Hoffman in his
monograph "The Menomini Indians," 14th Ann. Rep. Bur. Ethnol., 1896.
He wrote (p. 239): "Mourners blacken their faces with charcoal or ashes.
Formerly it was sometimes customary to add resin to the ashes, that the materials might remain longer on the skin, and a widow was not presumed to
marry again until this substance had entirely worn off."

SECOND JOURNEY
May 1846 to October 1848

FROM TORONTO TO FORT VANCOUVER
May to December, 1846

It is not the purpose of this article to describe in detail the route followed by the artist in his travels from Toronto to the Pacific coast and return, but to refer briefly to certain places visited, and to Indians encountered, of which drawings or sketches were made. The limited number that will be mentioned and reproduced are regarded as characteristic examples of his work.

Kane left Toronto May 9, 1846, and, after traversing Lake Huron, reached Sault Ste. Marie. The voyageurs with whom he traveled continued westward to the Lake of the Woods which they crossed June 7. Later in the month, after an uneventful journey, they arrived at Fort Garry at the junction of the Red and Assiniboine Rivers, the site of the present city of Winnipeg.

Fort Garry was referred to by Kane as "one of the best built forts in the Hudson's Bay territory. It has a stone wall, with bastions mounted with cannon, inclosing large store-houses and handsome residences for the gentlemen of the establishment." [4]

Three days before Kane's arrival at Fort Garry the half-breeds had departed for their summer buffalo hunt, and as he was anxious to witness the various events and to participate in the chase, he engaged a guide and 2 days later overtook one of the bands of hunters "at the Pambinaw River, and found the band cutting poles, which they are obliged to carry with them to dry the meat on, as, after leaving this, no more timbered land is met with until the three bands meet together again at the Turtle Mountain, where the meat they have taken and dried on the route is made into pimmi-kon." Different phases of the great hunt were sketched, and one of the finished paintings, made later in Toronto, shows many hunters with the famed Red River carts, some drawn by horses and others by oxen, setting out in search of the buffalo. The carts are laden with long poles, already mentioned, but on the return to the settlements, the load would consist of meat and pemmican. Another picture represents an en-

---

[4] This was the second Fort Garry, "within whose walls many scenes of excitement, hospitality and commerce took place during its existence from 1835-1882." Described in Bell, Charles Napier, The Old Forts of Winnipeg, 1738-1927. Trans. Hist. Sci. Soc. Manitoba, n. s., No. 3, Winnipeg, May 1927.

campment of the hunters on the prairie, with skin-covered tipis which did not differ greatly in appearance from a camp of the Cree with whom they were so closely associated. The artist's contact and intercourse with the métis hunters proved to be one of his most interesting experiences during the westward journey. The hunts were conducted twice each year and were entered into by the entire group of people. About the middle of June and of October they would meet on the White Horse Plain, some 20 miles west of Fort Garry, and would be formed into three bands, each taking a different route in their search for the buffalo herds. As Kane then wrote: "These bands are each accompanied by about 500 carts, drawn either by an ox or a horse. Their cart is a curious-looking vehicle, made by themselves with their own axes, and fastened together with wooden pins and leather strings, nails not being procurable. The tire of the wheel is made of buffalo hide, and put on wet; when it becomes dry, it shrinks, and is so tight that it never falls off, and lasts as long as the cart holds together."

A Red River cart, brought from Pembina, N. Dak., in 1882, is in the United States National Museum. The body is 4 feet 6 inches in length, and 3 feet 6 inches in width. The axle is 5 feet 9 inches in length, and the wheel is 5 feet 3 inches in diameter.

Kane left Fort Garry July 5, to continue toward the Pacific. He sailed from the mouth of Red River to Norway House, at the northern end of Lake Winnipeg, in a small sloop that belonged to the Company. From Norway House he crossed the lower end of the lake and entered the Saskatchewan River, which was ascended many miles to the Rocky Mountains. While ascending the Saskatchewan he passed Carlton House, Fort Pitt, and Fort Edmonton, as well as other trading posts of less importance. He left Fort Edmonton October 6 for Fort Assiniboine, on the Athabaska River. Soon Jasper House was reached, and thence, through ice and snow, he traveled over the mountains to Boat Encampment, on the headwaters of the Columbia. They floated rapidly down the Columbia, and 5 days later passed Fort Colville; Fort Vancouver was reached December 8, 1846.

ON THE PACIFIC COAST

December 1846 to July 1847

Kane remained at and about Fort Vancouver, "the largest post in the Hudson's Bay Company's dominions" some weeks, then went northward and arrived on April 9 at Fort Victoria on Vancouver Island. There he remained 2 months while "occupied in sketching ex-

cursions amongst the Indians in the neighborhood and along the surrounding coasts." The writer has had the pleasure of examining a large number of pencil sketches made by the artist during his stay on the West Coast but, unfortunately, many cannot be definitely identified, as Kane seldom placed marks of identification on his pencil sketches, a strange lack of foresight and one to be regretted.

Returning from the north, Kane arrived at Fort Vancouver June 20 and there remained until July 1,[5] when, together with a large party of the Company's men, he started on his return trip.

FORT VANCOUVER TO TORONTO

July 1847 to October 1848

On July 1, 1847, Kane, accompanying the Company's brigade of 9 boats, with between 60 and 70 men, departed from Fort Vancouver to begin his long journey homeward, during which he was destined to suffer much from exposure and to have many remarkable experiences before reaching his home in Toronto late the following year.

Advancing against the current of the Columbia the party arrived at Walla Walla July 12. This was on the left bank of the river, "a small fort built of *dobies,* or blocks of mud baked in the sun." From this post Kane made a trip to the interior and remained several days with Dr. Whitman at the mission that was so soon to become the scene of the atrocious crimes in which 14 persons, including Dr. Whitman and his wife, were murdered by Indians.

Having determined to cross overland from Fort Walla Walla to Fort Colville and there again join the Company's men, Kane set out from the former post July 29 and continued up the left bank of the Columbia. Soon he crossed the Snake River, which he called the "Nezperees River," and some 10 miles beyond encamped for the night. To quote briefly from his narrative of that date: "During the day we passed a large encampment of Nezperees, who were very kind to us, but stole a tin cup (a valuable article in that part of the world) I suppose as a souvenir of my visit. I took a sketch of a man, and might have frightened the chief into getting the cup restored to me by means of this sketch, but I had been so warned of the treachery and villany of these Indians, that I considered it too dangerous an experiment."

The original sketch to which Kane referred is reproduced in figure 3. It is a miniature in water color, a beautiful example of his

---

[5] Just 4 years later, on July 1, 1851, George Gibbs made a series of drawings of Fort Vancouver, Columbia Barracks, and other nearby places of interest.

work. The haste with which it was made is shown by its unfinished condition, only the head being worked out in detail, the upper part of the body being outlined but not filled in. The facial painting is most elaborate: Both cheeks back toward the ears are painted red, the chin is a purplish tint outlined with red, and the same purplish tint surrounds both eyes. Across the forehead are four lines of dark brown, and the same appears to have been used on the top of the head, forming with the red and purple a curious and unusual combination of colors. The lock of hair falling over the middle of the forehead was a characteristic custom of the tribe and, according to Mooney, caused the Kiowa to call them "Adal-katoigo," "people with hair cut across the forehead." A large painting later made from this sketch now hangs in the Museum in Toronto, but it was somewhat changed and a slender object was shown passing through the septum of the nose. This was evidently added to conform with the tribal name, although this particular tribe may never have followed the strange custom, and certainly this individual did not have such an ornament when the portrait-sketch was made.

Pushing forward, Kane and his companion arrived at Fort Colville during the night of August 8 and there remained several weeks. Frequent visits were made to the native village some 2 miles below the fort, "on a rocky eminence overlooking the Kettle Falls." Some sketches made at that time were later copied in oil, one of which represents a group of Indians watching two of their number play a game called "Al-kollock."

On September 21 word was received at Fort Colville of the murder of Dr. Whitman. The following day the two boats, each with a crew of six men, started up the Columbia for Boat Encampment, where they arrived October 10 and there awaited the coming of the party from the east, which did not appear until October 29. Boat Encampment was at the head of the navigable water, where three rivers unite to form the North Branch of the Columbia.

The goods brought from the east were soon transferred from the horses to the boats, and on October 30 the latter started down the Columbia for Fort Vancouver. Kane was now left with 4 Indians who were to drive the 56 horses back over the mountains. Fifteen horses carried the loads on the return trip, and all being in readiness, the party set out on the morning of the last day of the month. The trip over the mountains proved to be one of great difficulty. During the night of November 2 the thermometer dropped to 56° below zero, with ice and snow of great depth covering the land. Two days later the party reached the banks of the Athabaska River. The

stream was in flood and they were compelled to cross through the icy waters during a raging snowstorm. Food became scare. Jasper House was reached on the sixth, and there it was necessary to remain several days while snowshoes were being made. Jasper Lake was passed 10 days later, and on November 29, after enduring many hardships, the party arrived at Fort Assiniboine, "having travelled

FIG. 3.—July 29, 1847. Nez Perces. On bank of the Columbia River near mouth of Snake River.

350 miles in fifteen days." Kane remained 2 days at Fort Assiniboine, thence continued on to Fort Edmonton, where he arrived on December 5.

Fort Edmonton, on the left bank of the North Saskatchewan, was in the heart of the Indian country. As Kane wrote: "Seven of the most important and warlike tribes on the continent are in constant communication with the fort, which is situated in the country of the

Crees and Assiniboines, and is visited at least twice in the year by Blackfeet, Sur-cees, Gros-Vents, Paygans, and Blood Indians, who come to sell the dried buffalo meat and fat for making pemmi-kon, which is prepared in large quantities for the supply of the other posts." Buffalo were plentiful in the surrounding country, and many had recently been killed within a few hundred yards of the fort.

The vast territory controlled by the Hudson's Bay Company was divided into a number of districts, of which the Saskatchewan District was one of great importance. This included the region now being discussed. A list prepared in 1856 gave the Indian population of the district as 28,050. Fort Edmonton was the most important post in the District, the others being Carlton, Fort Pitt, Rocky Mountain House, Lac la Biche, Lesser Slave Lake, Fort Assiniboine, Jasper's House, and Fort a la Corne.[6] Edmonton was built in 1795, and Carlton House was erected in 1797, the latter being "a half-way house to Edmonton on the Saskatchewan" when going from Lake Winnipeg.

Kane did not depart from Fort Edmonton to return east until May 25, 1848, but during the early part of the year he made several long trips away from the fort. Early in January 1848 he went down the river to Fort Pitt and, so he wrote: "I spent a very pleasant and interesting month at Fort Pitt, surrounded by Cree Indians, this being one of their principal places of resort, and had ample opportunity of studying their habits and manners."

Soon after Kane arrived at Fort Pitt a Cree chief, Kee-a-kee-ka-sa-coo-way, "The man who gives the war-whoop," reached the post. To quote again from the narrative: "Kee-a-kee-ka-sa-coo-way is the head chief of all the Crees, and was now travelling through all their camps to induce them to take up the tomahawk and follow him on a war excursion in the following spring. He had eleven medicine pipe-stems with him, ten of which belonged to inferior chiefs, who had already consented to join in the expedition." An interesting account of his actions is contained in "Wanderings." The day was very cold, 30° or 40° below zero. The Cree agreed to show the stems to Kane. He unwrapped the pipes with much ceremony, then filled them "with tobacco and some other weed, after which he took off all his clothes, with the exception of the breechcloth.

"On my looking rather suspiciously at the clothes he had taken off, seeing they were rather old and filthy, he took notice of my doing so, and remarked, that although he possessed better, he was not al-

---

[6] Bryce, George, The remarkable history of the Hudson's Bay Company (Appendix C). New York, 1900.

lowed by the customs of his tribe to wear them, as he was then mourning the death of four of his relations who had been killed by the Blackfeet the year before. . . . . He then threw over his shoulders the skin of a wolf highly ornamented after the Indian fashion, and immediately removed the wrappers of leather, &c., that

Fig. 4.—January 1848. Kee-a-kee-ka-sa-coo-way, Cree Chief.

covered one of the stems, and inserting it into one of the bowls he had previously filled with tobacco, commenced a song which I could not understand." This continued some time, then "after some little prolonged ceremony, consisting principally of all present smoking from each stem as it was opened, he permitted me to sketch them, but never left the lodge until I had finished and he had carefully recovered and removed them."

The original water-color portrait-sketch of the bearer of the pipe stems, Kee-a-kee-ka-sa-coo-way, made on that midwinter day, is reproduced in figure 4. It reveals an individual with heavy features, unkempt, the lower part of the face painted red and the same red surrounding both eyes. An ornamented wolf skin rests on the left shoulder. A lock of hair, after the manner of the Cree, hangs down over the middle of the forehead. These details were characteristic of the tribe, and all had been mentioned some years before by Maximilian, who witnessed the arrival of a large party of Cree Indians at Fort Union, on the Upper Missouri River, June 27, 1833. He wrote at that time (p. 199) : [7]

Fig. 5.—January 1848. Two pipestems carried by Kee-a-kee-ka-sa-coo-way.

The Crees did not much differ, in appearance, from the Assiniboines; they are robust, powerful-looking men, with lank hair falling over their shoulders, and a broad flat lock, cut off straight over their eyes; one man, however, had it hanging down to his mouth. Some had their long hair plaited in several tails. . . . . Their faces were painted red, some with black stripes. . . . . Several of them wore wolf skins over their shoulders, with the head of the animal on the breast.

The similarity of the two descriptions is so great that the identity of the tribe to which the pipestem carrier belonged could be easily determined. The writer is of the belief that the large oil painting of Kee-a-kee-ka-sa-coo-way, now hanging in the Royal Ontario Museum of Archaeology, which was made by Kane after his return to Toronto, was based entirely on this small sketch, the elaborate costume, feathers, and pipestem being added.

[7] Maximilian, Prince of Wied, Travels in the interior of North America. London, 1843.

Two of the eleven pipestems sketched at that time are shown in figure 5. The outline of a pipe, made in pencil and not colored, appears at the right of the upper sketch. The stems were of great importance, the pipe bowls being of minor consideration.

Kane returned to Edmonton and there remained until April 12, when he was told that a large band of Blackfeet were soon to visit Rocky Mountain House to trade with the Company. Ever eager to see the Indians in their native surroundings he joined a party of 6 men, with 10 horses loaded with goods, and went from Edmonton to Rocky Mountain House, where, after an uneventful trip, they arrived April 21.

FIG. 6.—April 21, 1848. "Arrived at Rocky Mountain Fort. . . . In the vicinity was a camp of Assiniboin lodges, formed entirely of pine branches."

The fort—Rocky Mountain House—was beautifully situated on the Saskatchewan, on a small prairie about 180 miles southwest of Edmonton, with the Rocky Mountains rising in the distance. It was used during the winter season when the Blackfeet came to trade but was unoccupied in the summer. At the time of Kane's visit "a camp of Assiniboin lodges, formed entirely of pine branches," stood near the fort. Fortunately, he made a water-color drawing of this scene which is now reproduced in figure 6. Rocky Mountain House is in the distance with part of the Indian camp in the foreground. The words "Cree Lodges" appear faintly in the lower right corner of the sketch, but both Cree and Assiniboin Indians camped near the fort and all would have erected similar lodges.

Such primitive structures were used in the northern country, not always as permanent habitations but often as temporary lodges. In the latter capacity they served at Fort Union, on the Upper Missouri, during June 1833. Maximilian was at the post and wrote in his narrative: [8]

On the 26th of June, the arrival of a numerous band of Assiniboines was announced to us by several messengers. . . . . Towards the north-west, the whole prairie was covered with scattered Indians, whose numerous dogs drew the sledges with the baggage.

Later, after the arrival of the Assiniboins, he continued:

On the west side of the fort the Indian women were engaged in erecting temporary travelling or hunting huts, composed of poles, fixed in the ground, and the dog sledges set up against them, and covered with green boughs, as they had brought only a part of their baggage.

The grouping of the bough-covered lodges, with the fort beyond, would have resembled the sketch made by Kane at Rocky Mountain House a few years later.

Another reference to structures similar to those just mentioned is to be found in a work treating of an earlier generation, and of another part of the country. Alexander Henry, when recording events of the year 1767, referred to his arrival in the vicinity of Michipicoten, on the north shore of Lake Superior, which he chose for his "wintering-ground," and wrote (p. 215): [9]

On reaching the trading-post, which was an old one of French establishment, I found ten lodges of Indians. They were *Gens de Terres*, or *O'pimittish Ininitwac*, of which nation I have already had occasion to speak. . . . . Their lodges . . . . have no covering, except the branches of the spruce-fir.

These were the wandering hunters, known to the French as the Têtes de Boule, [10] an Algonquian group who ranged through northern Quebec. As Henry elsewhere wrote (p. 60): "a peaceable and inoffensive race . . . . . They have no villages; and their lodges are so rudely fashioned, as to afford them but very inadequate protection against inclement skies."

The same form of habitation was described at a much earlier time, far eastward from the Great Lakes, where it may have been seen by

---

[8] Op. cit., pp. 200-201.

[9] Henry, Alexander, Travels and adventures in Canada and the Indian Territories, between the years 1760 and 1776. New York, 1809.

[10] Michelson discussed the Tête de Boule in Linguistic Classification of Cree and Montagnais-Naskapi Dialects. Bur. Amer. Ethnol. Bull. 123, Anthrop. Pap. No. 8, 1939.

the first Europeans to reach the northern wilderness. As related by Purchas, (p. 748) : [11]

The Island of Assumption, by the Savages called *Natiscotec,* standeth in 49. deg. The Savages dwell in houses made of Fir-trees, bound together in the top, and set round like a Dove-house. This . . . . is at the entry of the River into the gulfe of S. Laurence.

FIG. 7.—April 1848. Pe-a-pus-qua-num, a Cree Indian at Rocky Mountain House.

This was the large island now known as Anticosti.

While at Rocky Mountain House, Kane had sufficient time to make sketches with care and deliberation. He was less hurried and possibly less excited than when encountering a group of Indians on the prairie, who were always suspicious of his desire to take "their like-

---

[11] Purchas, Samuel, Purchas his Pilgrimage. London, 1614.

nesses." A portrait of a Cree Indian made at that time is an excellent example of his work. It is not mentioned in "Wanderings," nor was it copied in oil after the artist's return to Toronto. But it was described in a manuscript list of Kane's sketches as: "Pe-a-pus-qua-num, or *One that passes through the sky,* a Cree Indian living among the Assiniboines at Rocky Mountain House." The original water-color sketch is reproduced in figure 7. The face and neck are painted red, but under each eye, and possibly beneath the lower lip, is a tinge of blue. The characteristic lock of hair is divided at the lower end and rests on the nose. One small strand of hair extends down over each cheek and is decorated with white beads. A necklace of blue and white beads is also shown. This is one of the most finished portrait-sketches made by Kane during all his travels through the Indian country.

A water-color drawing of a white horse is reproduced in figure 8. The tail and mane had been painted red, with red dots on the body and short horizontal stripes on the legs. A large eagle feather was attached to the tail and a bunch of small feathers appears to have been fastened to the forelock. A bridle and a saddle pad and stirrups are shown. The horse belonged to a Blackfoot Indian, but where the sketch was made is not revealed—possibly at Rocky Mountain House, where the Blackfeet came to trade. The painting records a known custom of the tribe which was described by Maximilian while at Fort McKenzie, August 10, 1833.[12] A large group of Blackfeet visited the fort to trade, and, as was their custom, they carried presents. Maximilian wrote:

They advanced in small parties, headed by their chiefs, who always bring a present consisting either of some beavers' skins or of a horse. The first horses that we received in this manner were two greys and a light bay, which were variously painted with red, chiefly on the forehead, the shoulders, and the haunches, and marked on the legs with transverse stripes like a zebra, and on each side of the backbone with figures in the shape of arrow heads.

This account agrees well with the drawing made by Kane some 15 years later.

Horses had been used for many years by the Blackfeet. On October 14, 1754, Anthony Hendry, who had started from York Factory several months before, arrived among the Blackfeet at some point not far northeast from the site of the present city of Calgary, Alberta, and wrote in part concerning them (p. 337) :[13]

---

[12] Op. cit., pp. 262-263.

[13] Hendry, Anthony, Journal of . . . . 1754-1755. Proc. and Trans. Roy. Soc. Canada, 3d ser., vol. 1, 1907.

Their horses are turned out to grass, their legs being fettered: and when wanted, are fastened to lines cut of Buffalo skin, that stretches along & is fastened to stakes drove in the ground. They have hair halters, Buffalo skin pads, & stirrups of the same.

The buffalo skin pads, which served as saddles, and the stirrups also made of buffalo hide were probably similar to those shown by Kane.

Kane again returned to Edmonton.
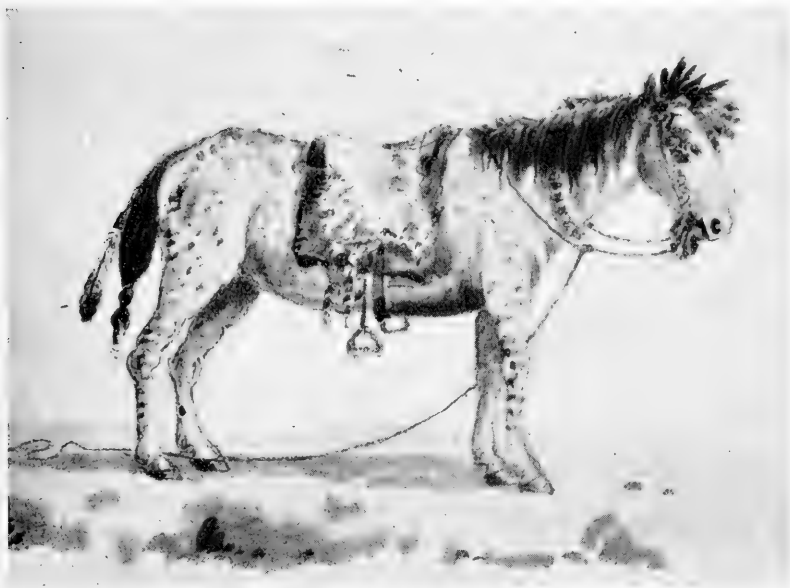
Fig. 8.—Blackfoot horse decorated with red paint and feathers.

On May 25, 1848, all being in readiness and the weather having cleared, a start was made from Edmonton. Twenty-three boats formed the brigade, with 130 men, bound down the Saskatchewan to Norway House. Thence, crossing the lower end of Lake Winnipeg, they soon entered Nelson River and continued down the stream to York Factory, on the shore of Hudson Bay, where the furs were placed on board ships to be carried to England.

Kane, having decided to return to his home in Toronto, left Edmonton with the brigade, as did the Catholic Bishop of Vancouver and several others who had come from beyond the Rocky Mountains, but they separated from the main party at Norway House.

Drifting rapidly down the river, they reached Fort Pitt the second day after the departure from Edmonton. Many buffalo were seen, and several large herds were encountered crossing the river and moving southward. At Fort Pitt two boats loaded with furs joined the brigade. In addition to the furs, to be sent to Europe, they carried much pemmican destined for distant posts where food was difficult to procure. These commodities came from "the Saskatchewan district."

On the first day of June, while the boats were floating down the Saskatchewan, "a large war party, consisting of Blackfoot Indians, Blood Indians, Sur-cees, Gros Ventres, and Pay-gans," was seen riding rapidly across the prairie and approaching the river bank. To quote Kane's description of the events that followed:

We instantly put ashore to meet them, and Mr. Harriett and myself met them on the banks of the river, leaving strict orders with the men to keep the boats afloat sufficiently near the shore for us to re-embark promptly in case of danger. They received Mr. Harriett, however, in a most friendly manner, he being personally known to numbers of them. They immediately spread a buffalo skin for us to sit down upon, depositing all their arms, consisting of knives, guns, and bows and arrows, on the ground in front of us in token of amity.

There was, however, one exception to this pacific demonstration, in the case of an Indian I had frequently heard spoken of before, named Omoxesisixany, "Big Snake." This chief walked around the party, cracking and flourishing a whip, and singing a war song, evidently desirous of getting up a fight, and refusing to lay down his arms with the rest, although frequently requested to do so.

Soon, however, Big Snake consented to take a "few puffs from the pipe which was going the round of the party," and peace prevailed.

Fifteen hundred warriors were in the party, in pursuit of the Cree and Assiniboin. This remarkable gathering of Indians was described by the artist as "the best mounted, the best looking, and the most war-like in appearance," of all he had encountered in his travels. The English and the Indians remained together until the following morning, a plan, so Kane wrote, "which was exceedingly acceptable to me, as it enabled me to make several sketches, and to hear something about them." He later mentioned having made several portrait-sketches at that time, one being that of Big Snake, and another of "Mis-ke-me-kin, 'The Iron Collar,' a Blood Indian chief, with his face painted red."

The sketch of Big Snake, made that evening on the banks of the Saskatchewan at some point not far from the mouth of Battle River, is shown in figure 9. No decoration of any sort appears—neither paint nor feathers. The original sketch of Iron Collar is also repro-

duced in figure 9. The entire face of the latter is painted red, and a gorget, appearing to have been made of metal and studded with embossed ornaments, crossed the throat. This was probably the "iron collar" which gave the Indian his name.

The brigade of boats continued on to Norway House, other boats joining them on the way, and all arrived safely. To quote again from "Wanderings": "Before leaving Norway House, some Cree Indians arrived, and boasted that one of their war chiefs had vanquished the great Blackfoot chief, Big Snake, in single combat." But the report was erroneous, and Black Snake lived another 10 years.[14]

Iron Collar Blood Indian Chief   *Big Snake – Blackfoot Chief*
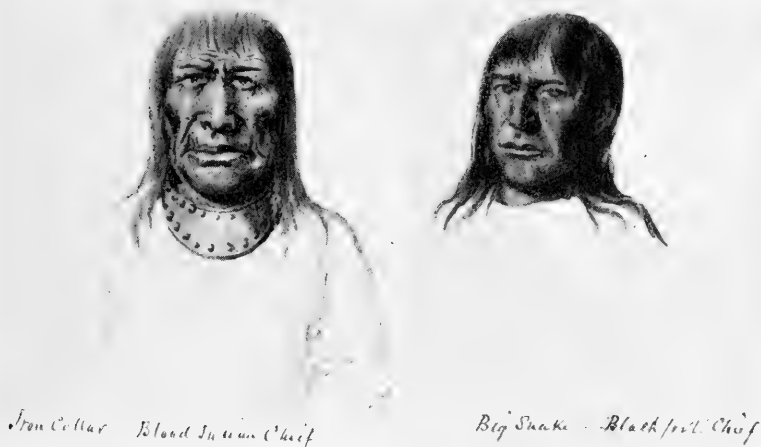
Fig. 9.—Two Indians met on the bank of the Saskatchewan below Fort Pitt, June 1, 1848. Left, Mis-ke-me-kin; right, Omoxesisixany, or Big Snake.

Carlton was reached June 5, and 5 days later the brigade stopped at Cumberland House. On June 12 they arrived at The Paw and

[14] I am indebted to John G. Carter for an account of Big Snake derived from various sources. The name of the Indian was "Big Snake, Oh-muck-see sin-a-kwan, or Loud Voice, also called Black Snake Man, a Piegan Chief." Again from the manuscript: "It appears that both the Big-brave and Elk-horn winter counts place the death of Big Snake in the year 1858.

"From all of the foregoing we conclude: That Big Snake was a chief of a band of the Piegan Indians; that in 1842 he ran off with forty head of horses and mules at Fort Union; that he was the father-in-law of White Calf; that he was announcer, or crier, and took a part in the treaty of October 17, 1855, at Judith River; and that he was killed in 1858."

there met Sir John Richardson and Dr. Rae, with two canoes, bound for the Mackenzie River in the endeavor to find Sir John Franklin. Norway House was reached on June 17, where, so Kane wrote: "the brigade left me, they going on to York Factory, and I remaining to meet Major McKenzie, who was expected soon to pass on his way to Fort Frances." After much delay, severe storms and head winds on Lake Winnipeg, and a delay of 4 days at Fort Alexander, Kane finally arrived at Fort Frances August 23. "Here the annual three months' voyage terminates, that being the time which it takes to convey the furs to York Factory, in Hudson's Bay, and bring back the outfit of goods."

Pushing forward from Fort Frances, through lakes and streams, with many portages, the artist reached Fort William, on the shore of Lake Superior, September 19. "On leaving Fort William, we suffered a great deal the next five days from the high cold wind, which frequently stopped our progress." Late on September 27 Kane arrived at Michipicoton where, during the year 1767, Alexander Henry established his "wintering ground." "The post," so wrote Kane, "is situated in a deep bay at the mouth of the river, and is surrounded by some of the best land to be found on the British shores of Lake Superior. The head chief of the Ojibbeways, who resides near the post, sat for me in his red coat trimmed with gold lace. These coats are given by the Company to such Indian chiefs as have been friendly and serviceable to them, and are very highly prized by their possessors. His name was Maydoc-game-kinungee, 'I hear the Noise of the Deer.'" The original portrait-sketch of the Ojibway chief, believed to have been the last portrait-sketch made by Kane, is reproduced in figure 10. Later a large copy in oil was made from the sketch and now hangs in the Royal Ontario Museum of Archaeology, Toronto. The later picture differs in some details from the water-color sketch, made on the shore of Lake Superior. In the finished painting only one head is shown on the medal worn by the chief, but in the original sketch two heads appear on the medal. It undoubtedly bore the portraits of Victoria and Albert.

On October 1, 1848, Kane arrived at Sault Ste. Marie and wrote in his narrative: "Here I consider that my Indian travels finish, as the rest of my journey home to Toronto was performed on board steam-boats."

The artist returned to Toronto safely after an arduous journey across the continent to the Pacific and return. He had succeeded in making innumerable sketches of the country through which he passed;

of many Indians, wild, barbaric members of western tribes; and of scattered posts of the Hudson's Bay Company. He had witnessed many stirring events during his years of wandering and had seen much that would now prove of the greatest interest to the historian and ethnologist, but, unfortunately, he failed to keep a journal and his "Wanderings" is all too brief and incomplete.

Fig. 10.—September 27, 1848. Maydoc-game-kinungee, Ojibway chief at Michipicoton on north shore of Lake Superior.

Among Kane's 100 oil paintings which were originally made by the artist for the Hon. George William Allan, later acquired by Dr. E. B. Osler, and by him presented to the Royal Ontario Museum of Archaeology, is one which deserves special mention, This is the largest canvas in the collection and is designated "Sioux Scalp Dance," with Fort Snelling appearing in the background. As Kane had never

visited Fort Snelling, on the right bank of the Mississippi at the mouth of the Minnesota River, it is strange that he should have made the painting. But the picture of the fort was based on a sketch made by the artist Henry Lewis in 1846 or 1848, a small copy of which he sent to Kane several years later. The drawing of the fort, in pencil, was made on a page of a letter from Lewis to Kane, part of which follows:
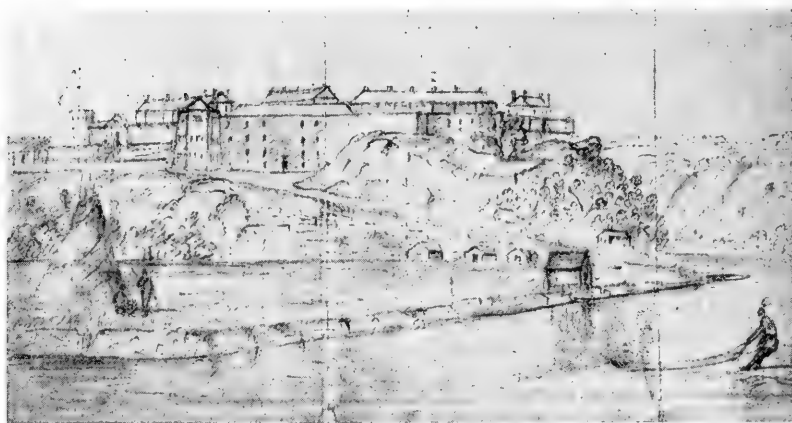
Fig. 11.—Fort Snelling. Sketched by Henry Lewis and sent by him to Kane.

MONTREAL, JULY 4TH

FRIEND KANE:

When I left your studio some months back to go and get my sketch book, I found the boat just ready to start . . . . . I did not come back again to show you the drawing of the fort. I now send you . . . . a slight sketch of Fort Snelling which may help you a little. It should have been sent long ago but much business drove the matter out of my head till yesterday when we were talking of you. . . . .

I remain truly yours
H. LEWIS.

Henry Lewis was the author of "Das Illustrirte Mississippithal," published in Germany in 20 parts between the years 1854 and 1857. A picture of Fort Snelling appears in the work, but it differs from the sketch sent by Lewis to Kane and which is now reproduced in figure 11.

Had Kane lived and been spared his sight, it is within reason to believe he would have continued his work among the Indians and would have added many pictures to those which he had already made, but fate decreed otherwise. His sketches and paintings will always be of interest, an interest which will increase as the years pass. They reveal phases of life which can never again be witnessed, so great are the changes wrought during the past century.

GEOLOGIC ANTIQUITY OF THE LINDENMEIER SITE IN COLORADO

(WITH SIX PLATES)

BY
KIRK BRYAN
AND
LOUIS L. RAY
Harvard University

(PUBLICATION 3554)
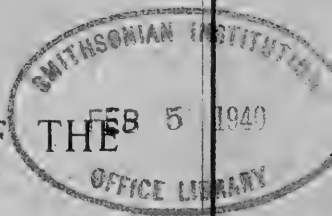
The Lindenmeier Valley viewed from the west. Piracy by a tributary of Boxelder Creek has beheaded the valley. High Plains escarpment to left, Colorado Piedmont to right.

GEOLOGIC ANTIQUITY OF THE LINDENMEIER SITE IN COLORADO

(WITH SIX PLATES)

BY
KIRK BRYAN
AND
LOUIS L. RAY
Harvard University

CONTENTS

ILLUSTRATIONS

PLATES

1. Lindenmeier Valley from the west.
2. 1, Lindenmeier Spring.
   2, Brennigan Spring.
3. 1, Kersey site and terrace.
   2, Prairie Divide, showing slump masses.
4. The Home moraine.
5. 1, View across Home moraine to erratics on south valley wall.
   2, Corral Creek moraine.
6. 1, Outwash plain below Corral Creek cirque.
   2, Protalus rampart of Corral Creek cirque.

TEXT FIGURES

GEOLOGIC ANTIQUITY OF THE LINDENMEIER SITE IN COLORADO

By KIRK BRYAN and LOUIS L. RAY

Harvard University

(With Six Plates)

INTRODUCTION

The antiquity of man in America is a problem of many ramifications which is as yet largely unsolved. The geologic approach is attended with difficulties which arise from the lack of immediate precedent as to method and from the lack of a well-established geologic chronology applicable to the whole world. However, the extensive culture layer at the Lindenmeier site in Colorado, containing a wide variety of stone implements associated with the bones of extinct animals, provides an unparalleled opportunity for an approach to the problem on several lines. The methods evolved and the chronology established during a 4-year campaign are here set forth. The chronology is, however, local, and its correlation with a time sequence of world-wide recognition involves numerous assumptions whose validity requires confirmation. The European chronology is being continually improved and is, as yet, not directly applicable to North America. Only by extensive studies of late Pleistocene time from the geological, paleontological, and archeological standpoints will a thoroughly sound world-wide chronology be attained. By the convergences of lines of evidence derived by these three methods, combined with the results of paleobotany, it will be possible eventually to date events of the Pleistocene in western United States in terms of the chronology already available in northern Europe.

Interest in the later phases of the geologic story in North America has, heretofore, lacked the stimulus provided by archeological finds in deposits of geologic antiquity. Many badly authenticated or even fraudulent discoveries, purporting to have some measure of antiquity, have cast a cloud of suspicion on claims of the presence of any man in North America earlier than the late-neolithic American Indian. However, in 1927, the discovery of the fluted points, now generally called Folsom, in association with extinct bison (Figgins, 1927, and Brown, 1929), led to a veritable revolution in thought among con-

servative anthropologists. Here, for the first time, implements distinct in type from the ordinary "neolithic" points, characteristic of the American Indian, were indubitably contemporaneous with an extinct animal. The considerable antiquity thus implied was admitted promptly by many leading anthropologists and led to much activity. From the three standpoints of typology, of vertebrate paleontology, and of general geology, further progress appeared possible.

Unfortunately, conditions at the original site were not favorable for geologic dating (Bryan, 1929 and 1937; Roberts, 1935). Furthermore, a reconsideration of the known stratigraphic position of extinct vertebrates indicates that many species may have survived into comparatively recent time (Romer, 1929 and 1933). Mere association with the remains of extinct animals is no longer considered a measure of an antiquity as early as, or earlier than, the climax of the last glaciation. Many extinct species are now thought to have survived into the last few thousands of years. These species are considered to be definitely Late-glacial, or Post-glacial in the European sense.

Many observers, both trained archeologists and a great group of amateurs, have enlarged our knowledge of the distribution of Folsom and Folsom-like points. Many finds of points associated with extinct animals have been reported (Cook, 1927; Schultz, 1932; Figgins, 1933; Sellards, 1938; Bryan and C. N. Ray, 1938). Also, other stone cultures of considerable antiquity have been discovered (E. W. and W. H. Campbell, 1937; Bryan, 1938; C. N. Ray, 1938), so that now we are confronted, not with a single problem of antiquity, but with a group of problems.

In order that the geologic method of attack may be used in dating the increasing number of finds of Folsom and other cultures, it is necessary to establish: 1, that the cultural objects are associated with a definite bed or beds; 2, that these beds are related to some definite geologic event; 3, that this event is related to other events or is of wide geographic extent; 4, that this event and related events are also related to some known geologic chronology. Such a sequence is obviously a rigorous requirement which may not always be met.

The foregoing relations appear to be characteristic of the Lindenmeier site, discovered in 1934, and intensively investigated by Dr. F. H. H. Roberts, Jr., of the Smithsonian Institution, from 1934 to 1938. Here, as described by Roberts (1935, 1936, and 1937), there is a layer of dark earth, containing bones of extinct animals and artifacts, buried in places under material 14 feet thick. This layer has been traced in outcrop and by excavation for more than 2,000 feet east and west, and more than 300 feet in a north and south direction.

Archeologically, the site is the most important find of recent years, because it has yielded over 2,000 stone implements, including, besides the typical fluted points, other points, and a wide variety of scrapers and similar artifacts, sufficient to define the stone culture by typology. Thus, the date of the culture becomes of importance.

The culture layer lies on the floor and southern slope of a valley abnormal in the area. Locally, this valley, because of stream piracy, retains part of its old floor, which is preserved downstream as a mere terrace remnant. Thus the valley and its culture layer may be related to a terrace which commonly occurs also on nearby streams. In this instance there are present the first two requirements mentioned above, the definite culture stratum, which can be related to a geologic event— the formation of the unusual Lindenmeier Valley, and of the con-. temporaneous terraces in the local streams.

These streams are small and ephemeral tributaries of a perennial river, the Cache la Poudre, which rises in the mountains and flows out onto the plains. The terraces of the tributaries may be traced down their courses and correlated with those of this main river. The Cache la Poudre is in turn a tributary of the master stream of the region, the South Platte River (see map, fig. 1), which drains most of the northern part of the Colorado Front Range and the adjacent Colorado Piedmont. As the present gradient of the South Platte River is a local base level, and as its successive positions in the past have been local base level, it follows that the terraces of all the streams in the region are similar in number and relative age. Thus, the third requirement is fulfilled, that the geologic event be of wide geographic extent.

Furthermore, the Cache la Poudre and other major tributaries of the South Platte, rise in the Rocky Mountains, an area recently glaciated. Some. of the terraces, particularly the lower and younger terraces here involved, may be traced upstream and related to the epi- sodes of glaciation in the mountains. Now, glaciation is a phenomenon that is world-wide. In the past the glaciers were not only more ex- tensive than now, but formed and advanced at least four times during the Pleistocene. Although there is no absolute proof that growth and advance of glacial ice was synchronous over the earth, nevertheless, there is much confirmatory evidence, such as an apparent uniformity in the total number of major ice advances, and an equally close similarity in the episodes attending the final retreat of the last great glacial advance. Thus, glacial chronology is, if not a perfect time record, at least a standard chronology.
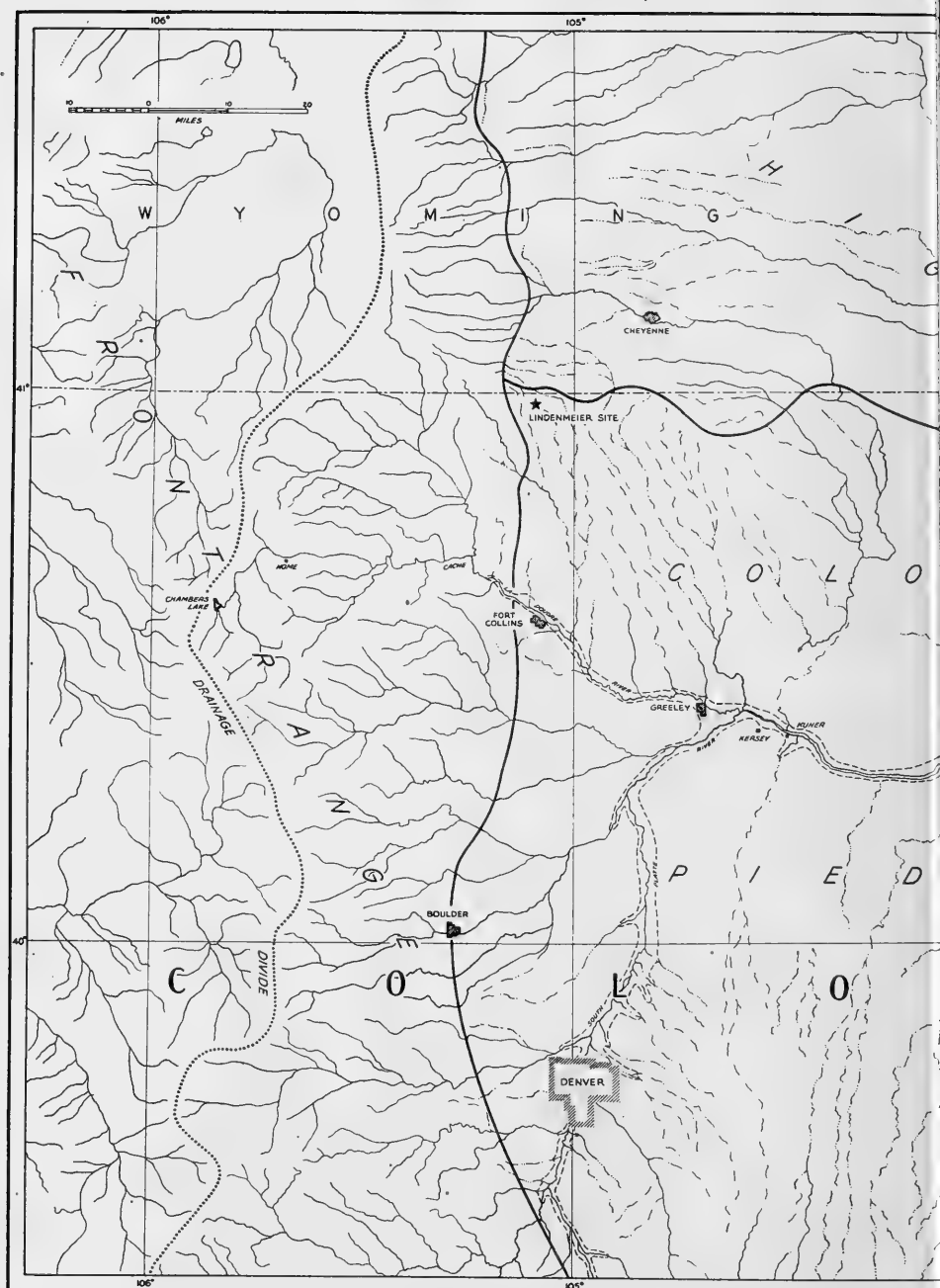
FIG. 1.—Map of the major physiographic subdivisions a

NEBRASKA

COLORADO

KANSAS

103° 102°

41°

40°

NORTH PLATTE RIVER

FRENCH

JULESBURG

SOUTH PLATTE RIVER

FT. MORGAN

FRONT

ARIKAREE RIVER
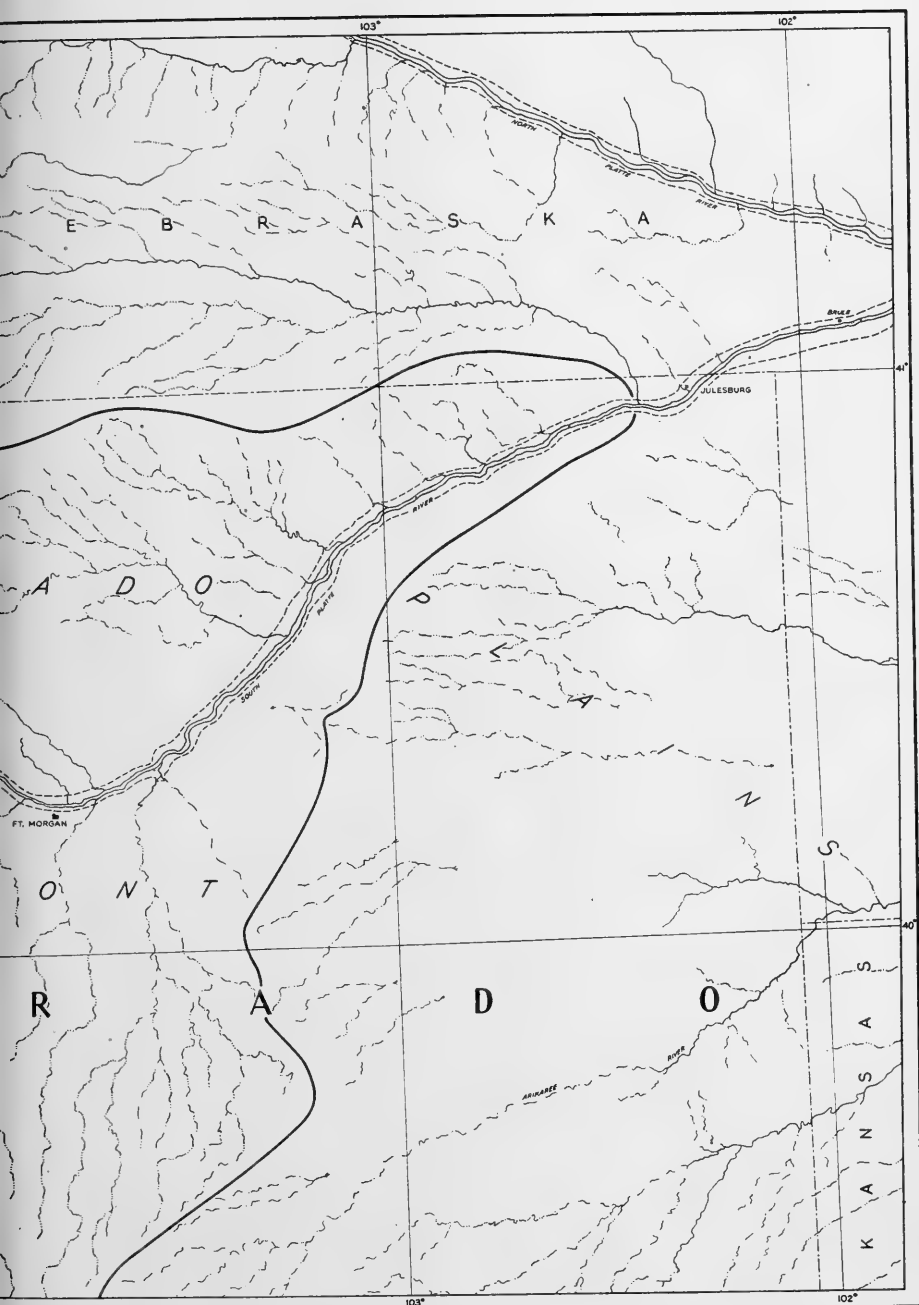
...nage of northeastern Colorado and adjacent territory.
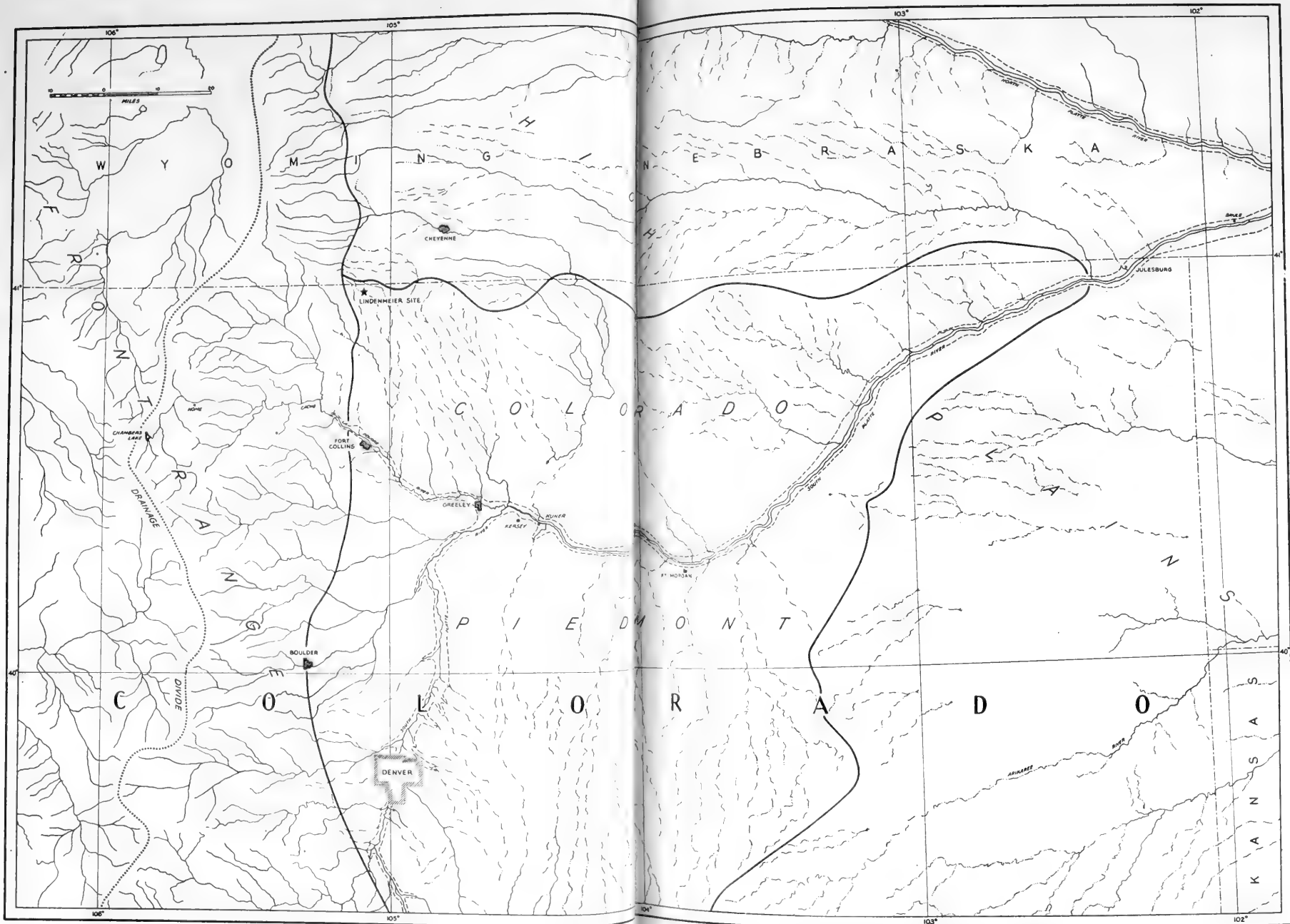
FIG. 1.—Map of the major physiographic subdivisions rainage of northeastern Colorado and adjacent territory.

ACKNOWLEDGMENTS

GENERAL GEOLOGY OF THE LINDENMEIER SITE AND ADJACENT REGIONS

GENERAL STATEMENT

The Lindenmeier site is located in an area of complex physiographic expression, immediately east of the Colorado Front Range, and on the break in slope between the High Plains and the Colorado Piedmont (fig. 1). The little valley which contains the site owes its unique topography and availability for the accumulation and preservation of cultural remains to circumstances which can be understood only if the character and origin of these major physiographic divisions are explained.

THE TERTIARY BEDS OF THE HIGH PLAINS

Following the uplift of the Colorado Front Range in the post-Cretaceous period of disturbance, streams flowing from the newly risen mountains reduced the border of the mountains to a smooth plain and thereafter spread a mantle of alluvium eastward over a broad piedmont area. This alluviation with intervening periods of erosion continued through much of Tertiary time. In the region studied, the great apron of Tertiary alluvium forms the High Plains and consists of the Brule tuff-clay (Oligocene), and a body of more or less consolidated sand and gravel, divided into two formations: the Arikaree (Miocene) and the Ogallala (Pliocene). These three formations are separated from one another and from the underlying pre-Tertiary rocks by unconformities. As originally laid down, the Tertiary formations lapped on the lower portions of the present mountain area. Erosion has, however, almost completely stripped the mountains of this mantle of detritus, which persists only as small isolated remnants within the mountain area. Only to the west of Cheyenne, Wyo., do the High Plains and the Tertiary cover rocks now extend as far as the mountain front, in the well-known "gangplank," by which the Union Pacific Railroad reaches the core of the mountains on an easy grade.

Field work indicates that the High Plains surface of southern Wyoming is in part erosional and in part depositional. A restoration of the High Plains surface in the vicinity of Cheyenne shows that it was once a featureless plain, sloping gently eastward at 50 to 100 feet per mile. Streams have now entrenched themselves on this surface so that the original plain is represented only by tabular, eastward-sloping interstream areas. Because of the scant rainfall and the pervious character of the underlying Tertiary Arikaree and Ogallala formations, the streams of the High Plains are mostly intermittent, as shown in figure 1. Only a few of these intermittent streams have succeeded in cutting through the pervious beds to the ground-water table, held up by the underlying impervious Brule tuff-clay. Without this permanent ground-water supply the streams cannot maintain a perennial flow. Nearer the mountains, where the rainfall is greater, the streams have been able to tap the ground-water flow and on this account have been able to excavate great basins from the original High Plains. With the incision of the South Platte, and also its companion stream, the Arkansas River, far to the south, many tributaries attained perennial flow. The Colorado Piedmont was, because of the process thus initiated, excavated as a lowland below the High Plains surface.

CHARACTER OF THE COLORADO PIEDMONT

During the excavation of the Colorado Piedmont, pauses in the downcutting of the Cache la Poudre-South Platte and their tributaries led to the development of a series of gravel-capped erosion surfaces, or pediments. Each surface bevels the underlying rock and slopes gently toward the Cache la Poudre-South Platte Rivers and, when followed downstream, becomes a narrow shelf or terrace. This step-like succession of pediments lies between the mountains on the west and the escarpments of the High Plains to the north and east. During this long period of stream excavation and pediment formation, a complicated series of drainage changes has taken place along both the major and minor streams. The courses of many of the minor streams have become adjusted to the north-south structure of the Cretaceous sandstones and shales of the Piedmont area. The northern tributaries of the Cache la Poudre-South Platte Rivers have worked headward, capturing eastward-flowing streams and diverting them (fig. 1). Furthermore, these tributaries, because of their steeper gradient and greater activity, have pushed back the more or less well-defined scarp which forms the boundary between the Colorado Piedmont and the High Plains.

The topography of the scarp between the Colorado Piedmont and the High Plains has been accentuated by ground-water sapping where-ever the spring zone, which marks the perched ground-water table along the upper surface of the impervious Brule formation, has been exposed by the headward erosion of small streams. Because of the location of the Lindenmeier Valley along a portion of this scarp, far from the main drainage streams, the Lindenmeier Valley has been preserved as an unusual topographic feature and archeological site (pl. 1).

ROCKS NEAR THE LINDENMEIER SITE

In the vicinity of the Lindenmeier Valley the rocks exposed in the escarpment consist of the Brule and Arikaree formations, which are here unusually thick and separated by an inconspicuous unconformity. The base of the Brule formation is a coarse conglomerate, which lies in channels on the pre-Tertiary formations. The conglomerate, 5 to 50 feet thick, is a stream-laid deposit which is overlain by clay and tuff having an estimated thickness of 350 to 400 feet. The color of the lower tuffaceous beds ranges from a drab yellow to a reddish buff, and the color of the upper tuff beds is white or slightly pink. The upper tuff is massive, almost without lamination or other evidence of the method of deposition.

Overlying the Brule formation is the Arikaree, which consists of poorly cemented arkosic sand and gravel. The gravel is composed primarily of angular to subrounded fragments of crystalline rock, and pieces of quartz and feldspar. From place to place the thickness of the Arikaree formation varies because of the irregularities of the underlying unconformable contact and of the beveling by erosion of the original upper surface of the formation during the development of the present High Plains. Near the Lindenmeier site there is a remaining uneroded thickness of at least 320 feet.

It is evident from the highly irregular bedding of the Arikaree formation that it was deposited in the channels of streams which during times of flood worked and reworked the material so that nearly all the finer debris was carried downstream and out of the area. The cement of this conglomerate is calcareous, and frequently the interstitial spaces between the small fragments of detritus may form a single calcite crystal. On weathering, the more firmly cemented beds tend to form small cliffs and in places overhanging rock shelters of small size.

SPRINGS AND THEIR SIGNIFICANCE

At and near the contact of the pervious Arikaree and the underlying impervious Brule formation, ground water emerges in a spring zone. Springs along this contact are divisible into two types: 1, definite flows of water, issuing at one or more places, and 2, large swampy areas. The point of issue is usually immediately below the Arikaree-Brule contact, and it appears that the water circulates in, and may be more or less confined to, a single point of issue by joints in the upper part of the Brule. Such a condition is well exemplified in a spring area about 6 miles west of the Lindenmeier site. At this locality, which is now dissected by deep gulches, the joints in the Brule formation are colored by limonite and have obviously served as channels of flow when the spring issued at an altitude somewhat higher than at present. The Brule has a further characteristic in that the fine pores of the tuff will transmit water by capillarity. Thus, water circulating in the joints spreads into the upper part of the formation and, where the overlying Arikaree formation has been removed, may emerge at the surface over a large area.

Whether the ground water emerges in a definite opening or over a large area as a swamp seems to depend on the local topography. If the area has been gullied, the water finds its way to the surface through a joint in the Brule and makes a definite point of issue, or spring. Such a spring is the one below the Lindenmeier Camp, in

the gully at the Lindenmeier site (pl. 2, fig. 1). In smoother topography, however, the water is brought to the surface by capillarity, and there broad swampy meadows develop. On Spottlewood Creek, sec. 19, T. 12 N., R. 68 W., there is such a meadow (pl. 2, fig. 2), and in sections 21 and 28 of the same township there is a broad meadow of about 30 acres.

Brennigan Spring, in section 30 of the same township, about 2.5 miles by road from the Lindenmeier site, illustrates both types of emergence of water. Here water pours from definite openings into the adjacent gully to form a small stream. Also, there are areas of a few square feet to as much as an acre, where water seeps to the surface. Swampy ground with a vegetation largely of sedge exists on flat places and also on hillsides with slopes as high as 15 to 20 degrees. A test pit showed, above the white tuff of this swampy tract, about 3 feet of dark earth, containing plant remains and formless humus.

Both the springs and swampy areas are of great economic importance in this region, where most of the land is utilized for grazing purposes. In this semiarid climate, with an average rainfall of about 16 to 20 inches (Martin, 1930), little unirrigated land is tilled. Dry farming is too precarious an occupation to be generally successful. Grazing is the dominant industry, especially in the areas where springs and swampy meadows dot the short grass plains with bovine oases of succulent food and drink. Range cattle limit their grazing according to distance from the springs, to which they can easily return. The Lindenmeier site lies almost surrounded by the winter range of the great Warren Livestock Co., whose sheep are lambed each spring on the green grass of the swampy meadows.

CLIMATE AND ITS INFLUENCE

Although the mean rainfall in the country immediately adjacent to the Lindenmeier site is estimated at from 16 to 20 inches, its effectiveness is limited because of the high rate of evaporation, the permeability of the surface rock and soil zones, and the irregular torrential character of the precipitation. At present this region supports a general vegetative cover of grama grass and mountain sage. Climatic fluctuations of the past may have radically altered the character of this cover. Evidences of such vegetative shifts may be found throughout the Great Plains. For example, stumps of a now extinct coniferous forest are reported along the valley of the Niobrara River in Nebraska (Aughey, 1876, p. 266), and even at the Lindenmeier site the last fringe remnant of an extension of the mountain forest onto

the plains was removed by the early settlers and has been unable to readvance over the ground lost through human destruction. Apparently the last climatic shift has been a trend toward greater aridity. If, on the other hand, a climatic swing toward more humid conditions be imagined, there would be an advance of the more humid plant associations into the present dry areas. Reconstructing the climatic conditions when glaciers occupied the mountain valleys, we should find a cooler, more humid climate, with consequent decreased evaporation. However, the region adjacent to the mountain front would be subjected to cold, drying winds, which blew across the mountains from west to east. Descending as cold winds from the mountains, they would be warmed and become drying winds in the plains region. Thus, whereas there might be expected a more humid climate with precipitation rising, in the vicinity of the Lindenmeier site, to twice the present amount, or to 40 inches, it would not follow that the vegetative cover would be a heavy forest such as one would normally expect in areas of similar precipitation in the Mississippi and Ohio Valleys. It is the writers' belief that along the mountain front there were, even in late Pleistocene time, extensive grasslands, with scattered coniferous parklike forests—a region suitable for browsing and grazing animals. Far from the major streams, which maintained a perennial flow, springs and water holes were the only sure water supplies and therefore attracted animals. In dry periods, particularly, the more extensive areas of swampy land proved as attractive then as now. Sheltered valleys such as the Lindenmeier, which contained a swampy area with springs and succulent grasses, were favorable for the congregation of animals and suitable for a camp of men who lived by hunting.

Considering this environment of the past with that of the present, it is necessary to reconstruct the many changes which have taken place since the valley was inhabited. By means of a careful and detailed study of the site itself and its relation to the regional changes which have taken place since the development of the culture layer, some concept may be gained as to the antiquity of the human artifacts.

THE CULTURE LAYER AND ITS LOCAL SETTING

The extent of the culture layer at the Lindenmeier site and its relation to the local topography have been developed by painstaking excavation. The facts lead inevitably to the conclusion that the culture layer was formed under local topographic conditions which no longer exist, and it must, therefore, have considerable antiquity.

A brief review of the results of excavation will make clear the local setting in which the culture is found and will serve as an introduction to those peculiarities of the topography which furnish evidence of the complicated chain of events that led to the formation and preservation of the culture layer. The intricate history of the drainage changes, piracies, periods of erosion and alluviation of the isolated Lindenmeier Valley will be first reviewed. Thereafter the chronological sequence at the Lindenmeier site can be correlated with the contemporary events of the surrounding area.

The culture layer at the Lindenmeier site, as described by Roberts (1935, 1936, and 1937), is a brownish black earth that ranges in thickness from a mere film to 2 feet. It crops out along the southern rim of the Lindenmeier Valley and slopes northward to the relatively recent arroyo. As exposed by trenches and test pits, it extends over a large area between letters S and C on the map (fig. 2). In the admirable sections by Roberts (1936, fig. 1) the position of the culture layer on a slightly irregular floor of the Brule formation is shown. Its dark color is in strong contrast to the white color of the floor. The culture layer is a sandy clay containing scattered pebbles, secondarily derived from the Arikaree. It is overlain by a rubble consisting of more or less rounded fragments of Brule tuff, but containing also fragments of feldspar, quartz, and various crystalline rocks, obviously derived from the conglomerates of the Arikaree. This rubble increases in thickness from south to north, toward the axis of the valley, and at the arroyo is 12 to 14 feet thick, as shown at 1 in profile UV, figure 3. The unequal sizes of the fragments, the irregular bedding and the irregular lenses of this rubble, which dip gently northward with the slope of the surface, all testify to its origin as a slope wash produced by the ephemeral run-off from a hill to the south. In the area where excavations have been made, there is no longer a hill to the south. One must suppose that the hill from which this rubble was derived once existed and that it has since disappeared. Furthermore, the culture layer was formed under a set of conditions during which this suppositious hill furnished little coarse debris, and thereafter conditions changed so that the run-off of rains brought in the rubble.

Not only must these facts be explained, but further, the area north of the gully has as yet yielded no artifacts. If one searches the north banks of the gully, he finds no culture layer. On the Brule tuff, there rests an alluvium, consisting of fairly thin-bedded gravel, composed of fragments of crystalline rock—all obviously reworked from the Arikaree, as shown at 2 in profile UV, figure 3. There are nu-

THE LINDENMEIER SITE
AND ADJACENT AREA

⋯⋯ = INTERMITTENT STREAMS
o = SPRINGS

0   500   1000
FEET

CONTOUR INTERVAL-20 FEET
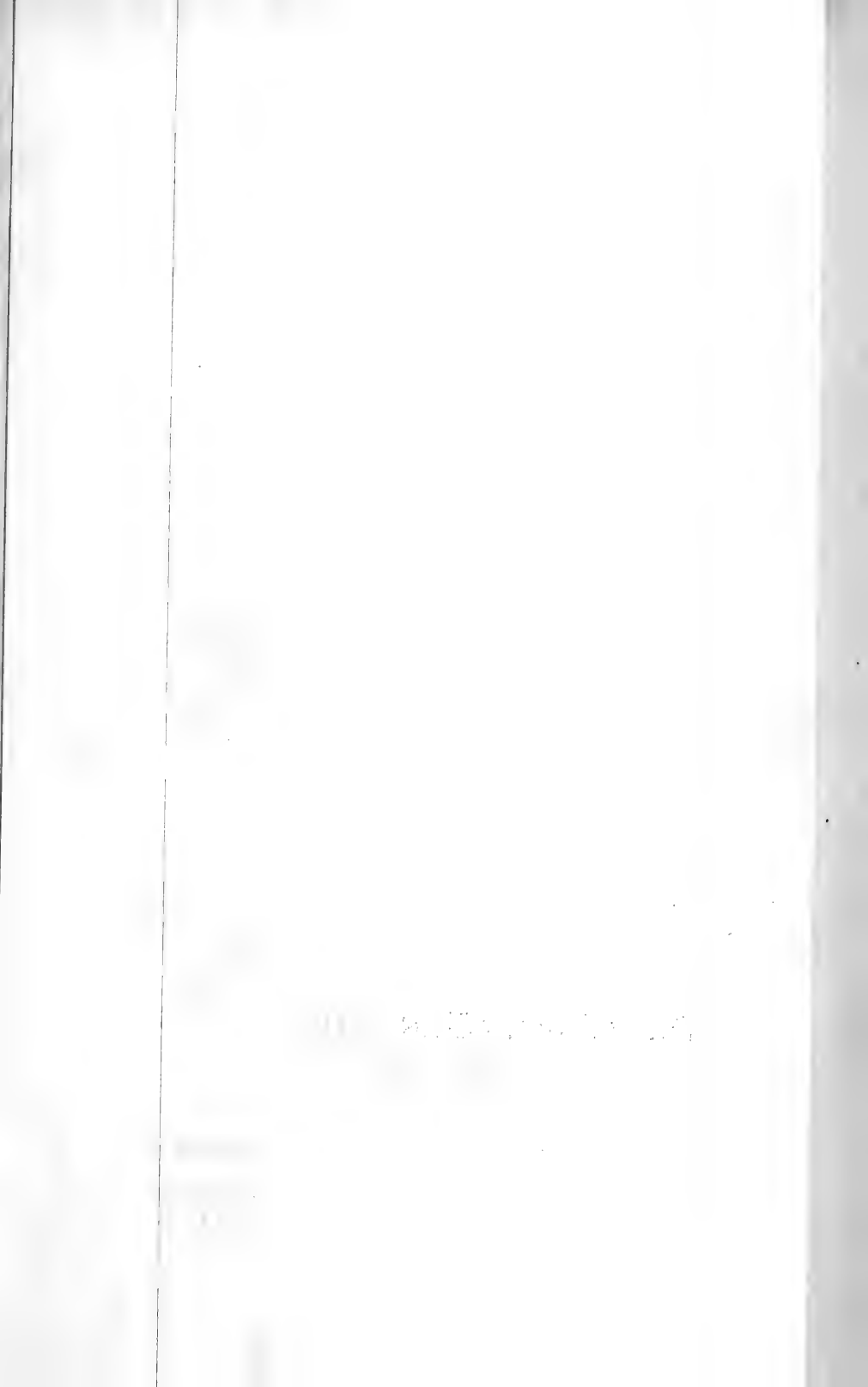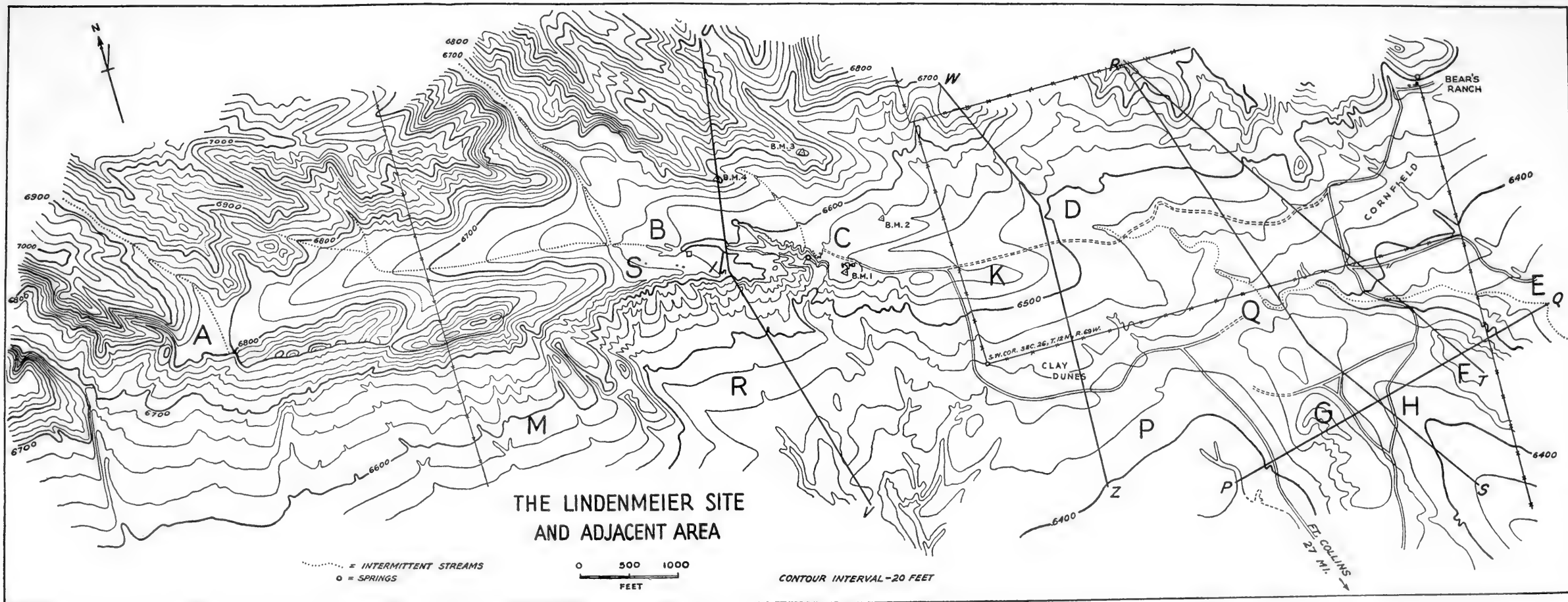
FIG. 2.—Topographic map of the Lindenmeier Valley. Letters indicate topographic features discussed in text and profiles shown in figure 3.

merous bands of dark soil, similar to the soil now underlying the grass roots at the top of the bank. It is obvious that this material was laid down rather slowly by ephemeral streams which had their origin in the areas of the outcrop of the Arikaree to the north and west. At one locality this same gravelly alluvium rests unconformably on a rubble of Brule fragments, similar to that above the culture layer. The gravelly alluvium thus appears to be not only different in origin, but also younger than the culture layer and its overlying rubble.
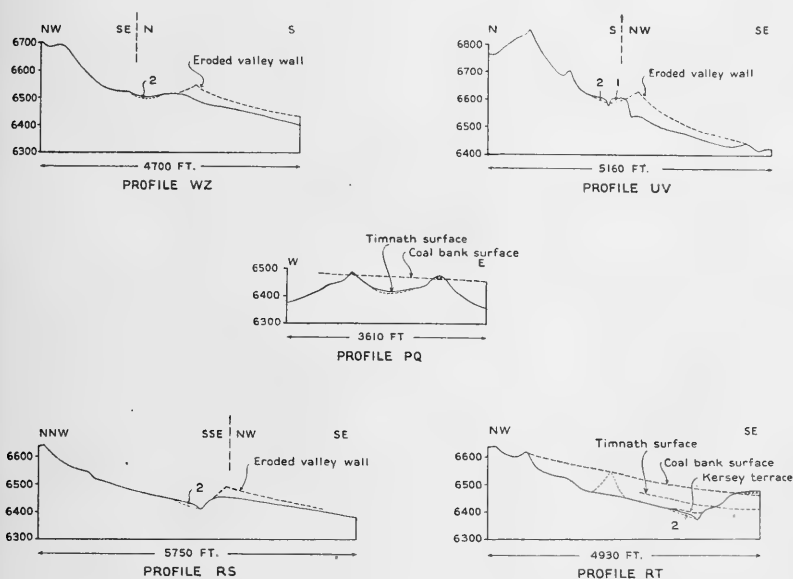
FIG. 3.—Profiles of the Lindenmeier Valley.

These details, proved by Roberts' excavations, present for analysis the following facts:

1. A valley floor on Brule tuff-clay, with overlying culture layer, containing extinct bison and camel.

2. A rubble of hillside wash, derived from a hill that has now disappeared.

3. A gravelly alluvium, free of cultural remains, which is derived from the west and north and is younger than the foregoing materials.

The history of the Lindenmeier Valley, thus recorded, is unusual. The form of the valley and its topographic details provide, however, a coordinated physiographic history into which these somewhat anomolous facts fit. The detailed topography of the valley becomes critical and must be examined at considerable length.

THE LINDENMEIER VALLEY

TOPOGRAPHY

The Lindenmeier Valley is shown in figure 2 and is also illustrated in the photograph, plate 1. It lies in the present drainage of Box-elder Creek, whose minor tributaries are in a continuous contest for drainage area. It lies also on the edge of the drainage basin of Spottle-wood Creek, whose tributaries at one time probably drained the area. In each period of the lowering of grades in the stages of erosion in the Colorado Piedmont, the contest for drainage area was accentuated. Piracies occurred, and one tributary gained the advantage of lower gradient and gained drainage area from the other. At the next stage another tributary had the lower gradient and with this advantage gained territory at the expense of the other.

Immediately north of the Lindenmeier Valley the gravel-capped ridges have a common slope to the southeast. Once this was a smooth plain, graded to the South Platte River, when its bed lay at elevations somewhat more than 200 feet above the grade of the present river at its junction with the Cache la Poudre. This episode in topographic development is the Spottlewood stage,[1] when the whole of the Colo-rado Piedmont consisted of a single smooth graded plain cut by the Cache la Poudre River and its tributaries.

In the next, or Coalbank stage (see p. 22), the South Platte River lowered its grade about 50 feet at its junction with the Cache la Poudre, and the topography of the Piedmont area became more accentuated. The aspect of the escarpment at the Lindenmeier site was much different from the present. The sloping ridges north of the site were outlined by shallow gulches which drained southeast into a broad plain, whose existing remnants are the flat-topped ridges G and F, figure 2. These ridges are capped by coarse gravel which lies unconformably on the underlying Brule formation and further to the southeast on Cretaceous shale. As shown by the profiles RT and PQ, figure 3, this plain lay 75 feet above the present floor of the Lindenmeier Valley, between points D and E, and about 150 feet above the grade of the present streams in the plain P, west of the ridge G (fig. 2). Remnants of this surface are not detectable in the

---

[1] The terms "Spottlewood," "Coalbank," and "Timnath," are defined on pages 21 to 24. They have been introduced by Ray as designations of the topographic surfaces or pediments of the synchronous gravel found on these surfaces, and of the time intervals involved in the production of these surfaces. "Pleasant Valley," "Kersey," and "Kuner" are also introduced as designations of three alluvial terraces, the gravels that compose them, and the corresponding time intervals.

upper end of the Lindenmeier Valley. It seems probable, however, that the existing ridges were outlined by gulches somewhat shallower than those of the present. The Lindenmeier Valley may have been already formed and may also have drained southeastward into the broad, smooth plain represented by the ridges G and F.

As the Coalbank surface lay at considerably higher elevations than the Arikaree-Brule contact, the valleys north and west of points G and F must have been dry. Ground water may have emerged to form broad swampy tracts in the plains represented by the ridges G and F, but no tangible evidence of such a condition is preserved.

In the next, or Timnath stage (page 23), the gradient of the South Platte River was lowered some 70 feet, so that at the junction of the Cache la Poudre it was about 100 feet higher than at present. The streams of the Lindenmeier Valley area were again incised. In the lower part of the valley the drainage was still southeasterly, and most of the area drained through the broad valley at point H, between the two ridges G and F. This valley, as shown in the profile RS, figure 3, lay 50 to 60 feet above the present floor of the Lindenmeier Valley. As shown in profile PQ, it lay at about the same altitude above the plain P, west of ridge G.

At this stage, it seems likely that the upper part of the Lindenmeier Valley, points A-C, was carved into almost its present form. As a well-developed valley with a general course slightly south of east, it may have drained into a broad valley that crossed the southern boundary of the present valley between the points K and Q, in figure 2. There is no proof, however, that it may not have been a tributary of the broad valley H.

The next lowering of grades was substantial, as the South Platte River was cut to a level below its present grade, or a total downward incision of more than 100 feet. This post-Timnath deepening of grade was followed by a refilling of the valley to a height of more than 50 feet above the present grade near the junction of the Cache la Poudre and South Platte Rivers, the Pleasant Valley stage. The river again cut down to, or below, its present grade, and refilled its valley to a height 30 to 40 feet above its grade, the Kersey stage. These events on the main stream were inadequately reflected on the tributaries. The post-Timnath and post-Pleasant Valley periods of cutting are merged into one period of downcutting. Even the period of filling of the main valleys, so well marked by the Kersey terrace, is inadequately shown. The Kersey terrace, when traced up the minor streams, particularly the Boxelder drainage, becomes lower, and the gravel decreases in thickness. Instead of a terrace composed of gravel

and representing a downcutting of the stream below the present grade, followed by a refill to a grade 30 to 40 feet above that of the present, the minor streams have a terrace consisting of a platform cut on bedrock, with a thin gravel cap that lies 10 to 20 feet above the stream grade. The terrace in the minor streams represents a single downcutting and widening of the valley. The process, however, was continuous throughout the post-Timnath period of cutting. The time of deposition of the Pleasant Valley and the time of the post-Pleasant Valley period of cutting are both included in the time of formation of the terrace whose completion corresponds with the end of the Kersey period of deposition.

In the post-Timnath to Kersey time interval, the Lindenmeier Valley took its existing form. Stream piracies occurred. An eastern tributary of Boxelder Creek, known as Sand Creek, gained the Lindenmeier Valley by headward erosion into the area D-E, figure 2, cutting into and diverting the drainage of the valley that formerly led into the existing dry valley, H. This newly formed valley in the area D-E also gained the upper Lindenmeier Valley by capturing its drainage at some point between C and D. Thus, all the area became drained on a more easterly course, and the Lindenmeier Valley took its present form and was widened to its present size. At a somewhat later period a tributary of Boxelder Creek, by way of another tributary that is also called Sand Creek, cut a deep gulch west of point A and thus beheaded the Lindenmeier Valley. The beheading of the valley is well shown in the photograph, plate 1.

The development of these piracies seems to represent a remarkable series of events. To them we owe the peculiarities of form of the Lindenmeier Valley and the preservation of the culture layer. The general reasons for the piracies have already been stated, but the particular reasons for these piracies and for the times at which they occurred are not wholly clear. At least two factors were important. The tributaries of Boxelder Creek flow from the escarpment southward, and cross two sets of resistant beds. The outcrop of Cretaceous sandstones swings from the general north-northwest trend west of Fort Collins to a general east-west trend near Round Butte, about 4.5 miles south of the valley and site. Near and north of this locality the basal conglomerate of the Brule formation crops out. Thus each tributary of Boxelder Creek encounters resistance to downcutting by two resistant formations, the Cretaceous sandstones and the basal Brule. As each tributary encounters the most resistant of the Cretaceous beds at a slightly different level and as the basal conglomerate of the Tertiary is irregularly cemented, the factors of

resistance in downcutting operate on different streams at irregular intervals throughout any one period of downcutting. First one tributary is held to a higher gradient while another is able to cut downward and thus gain advantage at the headwaters. In the next interval of time, the other tributary may have the advantage.

The factor of ground water in piracy is too little considered, but its effects in an area such as this, where a strong spring zone exists at the Arikaree-Brule contact, cannot be disregarded. These springs are powerful agents in erosion because the emergent water dissolves the cement of the Arikaree and reduces the rock to gravel. It also softens the Brule tuff into a slippery claylike mass. Obviously an ephemeral stream reinforced by a spring is more powerful in extending its drainage than a similar stream without such help. In the beginning of the history of the area, up to the periods of the piracies, the grades of streams in the area of the Lindenmeier Valley were above the spring horizon, and the effects of the emergent·water were negligible. Farther to the south, the springs may have played a large role in the planation that occurred. Furthermore, the piracy from the east, which brought the Lindenmeier Valley into the drainage of Sand Creek in the post-Timnath period of downcutting, may have been largely brought about by the diversion of ground water in that direction by reason of the extension of Spottlewood Creek.

The period of piracy of post-Timnath time produced the Lindenmeier Valley, and, by the close of Kersey time, it was broadened and reduced to its present grade. This valley with its almost east-west course, its low rim to the south and its swampy floor, slightly incised below the Arikaree-Brule contact, was a suitable camping and hunting ground for the Folsom people.

Modifications of the valley were, however, in progress. Streams heading in the ridge on the south flank of the valley have a direct course to Boxelder Creek and by headward erosion produced the plain M-R-P, figure 2. These streams by headward erosion reduced the ridge or southern wall of the Lindenmeier Valley at two levels of erosion. On the west the streams cut the plain M nearly 75 feet higher than the plain R-P on the east. This plain appears to have been cut at the Timnath stage. The lower plain, however, reached its present smooth grade in the Kersey stage and downstream merges into the 20-foot terrace of the streams. The form of the upper portion of the valley and the thinning of the southern wall by this process of headward sapping is shown in profile WZ, figure 3.

It is obvious that the streams on the grade of the plain R-P (fig. 2) were most successful in reducing the valley wall, which became a low,

rounded ridge. Even today this ridge is being reduced, and the former floor of the Lindenmeier Valley crops out as a dark layer on the white Brule tuff-clay from points S through C to K, except where protected by blocks of Arikaree derived from slopes that have now disappeared. This relation is brought out in profiles WZ and UV (fig. 3).

The lowering of grades and abandonment of the Kersey terrace on the South Platte River was followed by a period of filling to a level 20 feet above grade to form the Kuner terrace. Since that time the river has cut to or below its present grade and formed the existing wide flood plain. These events are imperfectly preserved on the tributary streams. The Kuner terrace cannot be followed up the minor tributaries and appears to merge with their flood plains. In the area south of the Lindenmeier site, on the plain R-P, there is only a set of deep ravines to represent the post-Kersey series of events on the main stream.

Furthermore, the continued development of the plain R-P, figure 2, and the continued sapping of the south wall of the valley led to the loss of the ground water and finally to piracy of the surface drainage. During the period of occupation, as shown by excavation, the south slope of the valley and presumably a large part of the valley floor was covered by dark earth similar to material now underlying the spring meadows of nearby localities. Thus, the conclusion is forced that the valley floor was a wet and springy meadow, which stood at elevations 50 to 75 feet higher than the plain R-P, immediately to the south. As the plain advanced northward by the erosion of the dividing ridge, the hydraulic gradient between the valley and the plain became steeper. Eventually the ground water was drained out through one of the joints in the Brule. The diffused spring or wet meadow was converted into a definite spring opening at a lower level.

With the drying of the valley floor, hillside wash covered and preserved the old meadow soil and thus entombed the relics of the Folsom peoples. Furthermore, the valley was no longer as attractive to man and beast, whose activities would be transferred to the plain R-P. Thus, the rubble which overlies the culture layer is barren of fossil bone and almost barren of the relics of man.

The formerly moist Lindenmeier Valley thus dried up by groundwater piracy was drained by an ephemeral stream. This stream enfeebled by the piracy at A, was attacked in its lower portions by headward erosion in post-Kersey time. In the area E-D, figure 2, especially near the cornfield of Bear's Ranch, the original valley floor was

largely destroyed and persists only as a series of terrace remnants. This gully extended upstream past the site, a little past the point B, and was later filled by the alluvial deposit barren of cultural remains, which has already been described. In turn, this deposit has been eroded by the gully extending from B to C, figure 2.

The date of these events is unknown. Many valleys of the southwestern United States were eroded, filled, and again eroded within the period of Pueblo occupation (Bryan, 1926). It may be that these events lie within this very recent period of alternate erosion and alluviation.

The most striking event of relatively recent time is the formation of the gulch extending from the plain R-P to B, figure 2. This gulch, according to the local residents, antedates occupation of the area by the white man. It is about 70 feet deep near the point C, and is being actively deepened, widened, and advanced headward at the present time. The piracy of the surface drainage of the Lindenmeier Valley by this gulch is a logical aftermath of the piracy of the ground water. The existence of a spring within this gulch leads to softening and weathering of the Brule, to the trampling of the surface by animals, and to active wind erosion, by which small tuff-clay dunes were built (fig. 2), and to active gullying. For these reasons the original hill in the areas S to C was carried away by the ephemeral streams forming the plain R-P. Eventually that ridge was so lowered that the surface drainage poured over the ridge to form the beginning of the gully. As this gully, or gulch, retreats, the spring also retreats to the north and west, softening the Brule and preparing the way for active erosion during the periods of storm, when water pours into the gully from rains.

CONCLUSION

The successive stages during which the grades of streams in the region were lowered promoted and also timed the successive piracies by which the Lindenmeier Valley gained its present topographic form.

Here, in the interval when the main rivers were forming the Kersey terrace, was a relatively sheltered valley with water and grass, attractive to animals and an ideal site for a hunting camp. No doubt there were other such sites in the region, but at no other yet found has later erosion been so feeble as to preserve, and yet so active as to expose, the deposits of that time.

PEDIMENTS AND TERRACES OF THE COLORADO PIEDMONT

GENERAL STATEMENT

The northern part of the Colorado Piedmont was developed as a great lowland below the grade of the High Plains surface in several successive stages of erosion. Each stage was begun by a lowering of grade of the main river, followed by a stabilization of grade or by alluviation. Into this sequence of events the detailed story of the Lindenmeier Valley fits. By a consideration of the history of this larger area, the significant event at the site, that is, the formation of the culture layer, may be connected with an event having a large geographic range.

The first period of incision of streams below the original grades led to the development of a broad lowland in almost the same posi-
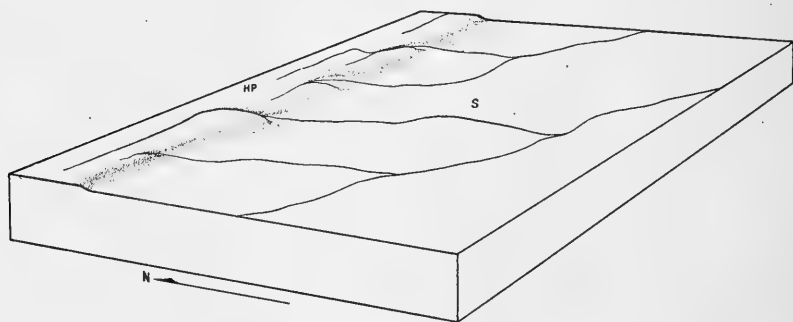
Fig. 4.—Generalized block diagram showing development of the Spottlewood pediment below the High Plains surface in the northern Colorado Piedmont.

tion, and having nearly the same area, as the present Colorado Piedmont. Within this lowland the tributaries of the Cache la Poudre-South Platte Rivers shifted from one position to another over the broad, sloping plains with comparative ease (fig. 4). Obviously the development of so large and so perfect a surface, even in rocks relatively as easily graded as the Tertiary and Cretaceous rocks of this area, must have consumed a considerable time.

This lowering of the stream grades within the Colorado Piedmont took place in post-Pliocene time and occupied most of the early and middle Pleistocene. It seems probable that each lowering of the grades, by which the pediments were formed, was due to uplift of both the mountain area and the western portion of the plains, as has been established for the similar sequence of events in Montana (Alden, 1932). On the other hand, during the Pleistocene there existed a

fluctuating climate, the effect of which on the grades of streams (Johnson, 1901) is as yet imperfectly understood.

This period of dissection was relatively long and efficient. After each incision of the streams there was stabilization of grades, and broad surfaces of erosion (pediments) were developed, which in places bevel the underlying deformed bedrock.[2] Each surface was more or less covered by a thin mantle of gravel—the channel deposits of the streams to whose lateral planations much of the development of the surfaces is due.

The last of the pediments was strongly dissected in the "canyon-cutting cycle," when the major streams cut to, or below, present stream grades. There are alluvial terraces younger than this period of canyon-cutting, and their distribution is restricted to narrow belts in the existing stream valleys. Each of these terraces records a filling of the valley and a reexcavation to, or below, the present grades of the major streams.

The gravel-capped pediments were formed in the earlier part of the Pleistocene. The terraces are, however, Wisconsin and later in age, and, as will be shown, are directly related to the later stages of mountain glaciation.

SPOTTLEWOOD PEDIMENT

The oldest and highest of the pediment surfaces (fig. 4) has now been so nearly destroyed that only a few scattered remnants yet rise above the younger erosion surfaces of the area. The name "Spottlewood pediment" is given to the surface because it is preserved along the escarpment between the High Plains and the Colorado Piedmont, in the headwater area of Spottlewood Creek, near the Lindenmeier site. It also forms the upper surface of Wildhorse Tit, a well-known landmark in sec. 23, T. 10 N., R. 64 W. (see Eaton Quadrangle). Remnants of the Spottlewood pediment are gravel-capped, and the term "Spottlewood" includes both the gravel and the time interval during which the pediment was formed.

Along the High Plains escarpment, in the vicinity of the Lindenmeier site, the Spottlewood pediment is represented by numerous gravel-capped spurs that slope gently southeastward and bevel the Arikaree formation. The high hills, approximately 16 miles west of

---

[2] Figures 4, 5, 6, and 7 are generalized block diagrams which represent the northern portion of the Colorado Piedmont in the Livermore and Eaton topographic quadrangles and adjacent regions. These are intended to give a general pictorial history of the development of the pediment and terrace surfaces and not to furnish details of the actual development in each minor area.

Wildhorse Tit [3] are relatively large remnants of this surface. Over-lying their cap of well-rounded stream gravel is a thin layer of wind-blown sand, which has at its base a layer of ventifacts. At the Lindenmeier site the Spottlewood pediment is preserved in the south-eastward-sloping, flat-topped ridges that lie to the north of the valley.

COALBANK PEDIMENT

Along the Cache la Poudre River and extending up its tributaries there are remnants of an easily recognizable pediment. On the main streams it has a grade about 50 feet below the Spottlewood pediment (fig. 5). Because it is well preserved on the high ridge 24 miles northwest of the junction of the Cache la Poudre and South Platte Rivers, it has been named the "Coalbank pediment," [4] a term ap-plicable to the synchronous gravel and the time interval involved.
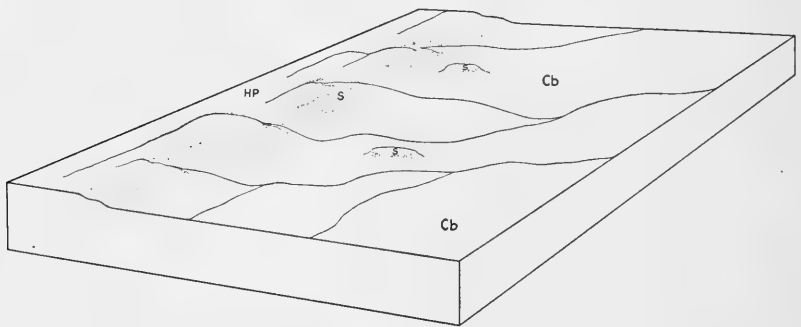
FIG. 5.—Generalized block diagram showing development of the Coalbank pediment below the Spottlewood pediment.

This surface, like the Spottlewood, bevels bedrock and is covered by a gravel cap, overlain by scattered ventifacts and wind-blown sand. It was formed during a period of stationary base level and lateral planation of streams. In the Coalbank stage the streams near the borders of the Piedmont area widened their floors into broad valleys, as shown in figure 5. However, planation did not continue long enough for the complete destruction by stream action of all the remnants of the previously formed Spottlewood pediment. These remnants, then as now, stood as hills and flat-topped ridges above the broad, sloping plains of the Coalbank surface (fig. 5). At the Lindenmeier site, as described on page 14, the Coalbank pediment is preserved in the form of two gravel-capped mesas, G and F, figure 2.

---

[3] These hills are 4 miles west of the railroad siding of Dover, a locality in the Eaton Quadrangle.

[4] "Coalbank" is the local name of the ridge between Lone Tree and Boxelder Creeks in the Livermore and Eaton Quadrangles.

TIMNATH PEDIMENT

A third period of stream incision, followed by planation by streams and the development of a broad valley stage in the tributaries of the main rivers, produced the Timnath pediment (fig. 6). This surface, the synchronous gravel, and the time interval are named for the village of Timnath.[5] The hills east of this village lie about 21 miles northwest of the junction of the Cache la Poudre and South Platte Rivers.

Near this junction the Timnath surface lies approximately 70 feet below the grade of the Coalbank pediment and about 80 to 100 feet above the river. Except that the areas of planation are smaller, this pediment has the same characteristics as the two older surfaces. In the vicinity of the High Plains escarpment, relatively narrow valleys
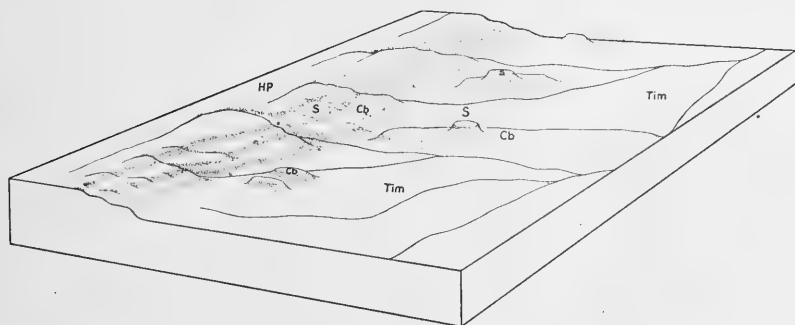
Fig. 6.—Generalized block diagram showing development of the Timnath pediment below the Coalbank pediment.

were developed, so that near the Lindenmeier site the most easily recognized remnant of the Timnath pediment is a flat-floored valley (H in fig. 2), lying between the two mesas that are, as previously stated, remnants of the Coalbank pediment.

The gradients of all the pediments steepen toward the mountain front and toward the escarpment of the High Plains. The pediment surfaces can be traced into the mountains, where they are represented by rock benches and spurs along the main drainage streams, and in a few localities by open valleys with subdued and terraced topography. Examination of the High Plains escarpment shows that the area of the Colorado Piedmont has not been much extended since the initial incision of the High Plains surface by the streams

---

[5] Timnath, a railroad station and village, shown on the Eaton Quadrangle, approximately 17 miles northwest of Greeley, Colo.

which cut the Spottlewood pediment. The Colorado Piedmont has been deepened and its borders diversified by newly cut canyons and gulches.

The South Platte River, above its junction with the Cache la Poudre at Greeley, has a course inconsistent with the slope of the Spottlewood and Coalbank pediments. However, the Timnath pediment is developed along the course of this stream. It appears, therefore, that at the beginning of the development of the lowland of the Colorado Piedmont, the Cache la Poudre and the part of the South Platte east of their present junction formed the main stream of the region. The upper part of the South Platte River appears to have been a tributary of the Arkansas River. In the interval of stream incision between the Coalbank and Timnath stages a tributary of the Cache la Poudre captured the waters of the large area drained by the upper part of the South Platte. This recently acquired drainage is larger and better watered than the original area, and the South Platte River has become the main stream of the region, reducing the Cache la Poudre to a tributary (fig. 1).

THE CANYON-CUTTING CYCLE

Following the development of the Timnath pediment, there was a new period of stream entrenchment. Not only were the streams of the Piedmont area deeply incised to grades below the present grades of the rivers, but great erosion occurred in the mountains. The streams of the mountain area cut canyons almost as large and as deep as their present canyons, and hence this period is known as the "canyon-cutting cycle" (Van Tuyl and Lovering, 1935). It is merely a repetition of the three preceding periods of incision, the pre-Spottlewood, pre-Coalbank, and pre-Timnath cycles. The severity of the entrenchment, both in the mountains and in the plains, is marked. Furthermore, it ushered in a new series of changes in stream gradients in which, between periods of incision, aggradation rather than planation was characteristic.

ALLUVIAL TERRACES

After the canyon-cutting cycle the main streams built up their channels with alluvium in successive intervals, separated by intervals of renewed downcutting (fig. 7). On the minor tributaries of the Piedmont area these changes are, however, not perfectly recorded.

The stages appear to have been short, and the minor tributaries were too feeble to accomplish complete gradation to the main streams at each successive change in grade.

A careful study of the valleys of the Cache la Poudre and South Platte Rivers has brought to light only a few remnants of the earliest and highest of the alluvial terraces. Later erosion has destroyed and carried downstream much of this material. Also, wind action has accumulated many dunes which so bury the areas adjacent to the rivers that remnants of terraces are concealed. The most extensive and most easily recognized terrace representing the maximum of valley filling is at the locality called Pleasant Valley, north of the confluence of the Cache la Poudre and the South Platte Rivers. The highest alluvial terrace is named for this locality, where the top of
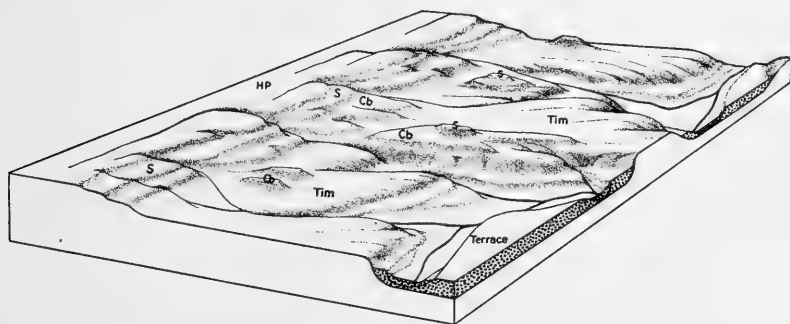
FIG. 7.—Generalized block diagram showing development of alluvial terraces in deep valleys cut into the Timnath pediment during the canyon-cutting cycle.

the terrace lies more than 50 feet above the river grade. The terrace consists mostly of sand with moderate amounts of gravel. Here, and in other localities, it is masked by wind-blown sand, and in many places merges topographically with the lower terraces. Terraces attributed to the Pleasant Valley stage may represent two periods of alluviation. The terrace remnants are so few and are so obscured that such a relation might exist without leaving easily detectable traces.

Strong stream erosion destroyed most of the alluvial fill represented by the Pleasant Valley terrace, and the main rivers once again cut down to, or below, their present grade. Deposition then began anew, and river gradients were built up to form alluvial plains now represented by a strong terrace, which is very well preserved, and forms the main agricultural area on the South Platte River. It is prominent near the village of Kersey, a railroad station, approxi-

mately 7 miles east and slightly south of Greeley, Colo. The alluvium of this terrace, as shown in numerous pits, is largely a fine-grained gravel and sand. Much of the surface of the Kersey terrace is covered by dune sand and by alluvial fans, especially on the borders away from the rivers (pl. 3, fig. 1). Its general surface lies between 25 and 30 feet above the present stream grade at the type locality. Near the valley walls the terrace surface may rise gradually to elevations of 40 to 45 feet because of accretions to the strictly river-laid fill. At places along the main streams and the tributaries the upper 2 to 12 feet of terrace gravel is deformed into an involuted and formless mass in which ventifacts may be found. This material is a characteristic warp attributable to intensive frost action in a severe and windy climate such as no longer exists.

Separated from the Kersey terrace by a well-defined scarp is the lowest recognizable terrace. At the type locality, near Kuner, a railroad station 5 miles east of Kersey (fig. 1), this terrace, to which the name "Kuner" is applied, lies about 12 feet above the river. Gravel and sand pits show that its composition is essentially the same as the older and higher Kersey terrace. In some places the surface of the Kuner terrace rises to as much as 20 feet above the level of the South Platte River.

The Kersey stage of alluviation was followed by erosion and the lowering of river grades to, or below, the present grade. The Kuner terrace represents a period of alluviation in which the river grades were not built so high as in the earlier stage. Again the rivers incised themselves and dissected the Kuner terrace. Between the Kuner terrace and the broad flood plain of the rivers no lower terraces have been detected.

MODERN FLOOD PLAIN

The flood plain of the South Platte and Cache la Poudre Rivers is broad, with a width ranging from a few hundred feet to a mile and a half. Across the surface the rivers flow in a channel which in places is braided, suggesting aggradation. The rivers, at ordinary low water, flow in channels 4 to 6 feet below the flood plain, as at Kersey, or less than a foot, as at Platteville. This variation is the result of the numerous irrigation dams which create, at moderate river stages, an artificial gradient. It is now impossible to measure the height of the lower terrace level above the natural stream grade, for one must use this artificial grade. However, the discrepancies between these grades are of small importance in the study of the higher surfaces. In spite of the dams, the river in times of flood covers the whole of the flood

plain, as attested by local residents, and thus it may be that the present artificial grade at low or medium stages is not reflected in the flood gradient, which may be identical with that existing before the dams were built.

The surface of the flood plain is not a perfect flat, but in a number of places there are small meander marks, abandoned stream channels, and gentle ridges and furrows 2 to 3 feet in height. None of these features seems to indicate the existence of a terrace younger than the Kuner, although many of them cannot be clearly interpreted. Materials composing the visible portion of the flood plain are of small size, containing none of the coarse well-rounded boulders characteristic of the higher terraces or of the river bed at the mouth of the Cache la Poudre Canyon. At many places there are thin lenses of sand and loam interbedded with equally thin beds of fine-grained gravel, composed of quartz and pink feldspar.

SUMMARY

As a result of uplift and dissection of the High Plains surface, three successive periods of incision and planation by the streams in the northern Colorado Piedmont have produced three successively lower gravel-capped pediment surfaces, cut on bedrock. Alternate incision and alluviation have produced three or perhaps four alluvial stream terraces at lower elevations. The important period of valley deepening, the canyon-cutting cycle, separates these two sequences of events and is of greatest value in the correlation of the history of the Colorado Piedmont with that of the mountains. As hereafter shown, the pediments and erosional surfaces, well developed in the soft sandstone, shale, and limestone of the Piedmont area, are now represented in the mountains by spurs on the canyon wall, which are relics of old broad valleys. The alluvial stream terraces can be traced continuously along the major streams from the Piedmont into the mountains, where each terrace ends at the moraine left by an ancient glacier. The alluvial terraces are thus directly correlative and synchronous with glacial stages.

GLACIATION OF THE CACHE LA POUDRE VALLEY

It has long been known that during the Pleistocene period the mountains of Colorado supported extensive valley glaciers. Even now small glaciers and permanent snow fields linger in sheltered cirques of the high mountains. The northernmost of these, Hallet Glacier, nestles in a cirque head on the northeast flank of Hagues

Peak, only 45 miles southwest of the Lindenmeier site and 25 miles due west of the mountain front. To the south, in similar cirques along the high crest of the Continental Divide, there are numerous ice and snow masses. Northward, and west of the area here considered, the peaks of the Colorado Front Range decrease in altitude and lie too low to support permanent snow fields under the present climatic conditions.

Although numerous descriptive studies have been made of the glaciers of Colorado and of other parts of western United States, there has been, with the exception of Blackwelder's comprehensive study (1931), little or no attempt at regional correlation of glacial stages. By the very nature of the problem, a great deal more data, both descriptive and quantitative, must be gathered before the complete picture can be brought into focus. Until that time, workers must be content with local chronologies and a correlation with continental glacial stages based on purely qualitative evidence.

General geologic thought, as summarized by Blackwelder (1931), assumes that the last advances of the valley glaciers in the Colorado mountains, and elsewhere in the Rocky Mountains, were contemporaneous with the advances of the continental glaciers in Wisconsin time. This assumption is granted by the writers and is used as one of the bases for correlation.

In the drainage basin of the Cache la Poudre River there is definite evidence for one glacial stage of pre-Wisconsin age and three glacial substages of Wisconsin age. There is reason to believe that a fourth substage, the earliest Wisconsin, occurred but left so few traces that its existence is not completely proved. Furthermore, a fifth substage is represented in this region, not by the morainal relics of glaciers, however small, but by the less prominent effects of a strong refrigeration of climate. These glacial stages will be reviewed in a chronological order, from the oldest to the youngest.

PRAIRIE DIVIDE GLACIAL STAGE

The oldest glacial deposit of the Cache la Poudre drainage forms the surface of Prairie Divide, a broad mountain flat, with an altitude of approximately 7,900 feet (T. 10 N., R. 72 W., Livermore and Home Quadrangles). Here, weathered gravel rests upon a deeply weathered glacial till. The gravel and till form a plain, so perched above the level of the present drainage that it is being eroded from all sides. Great bodies of slumped material fill valleys which have cut headward into the mass (pl. 3, fig. 2). Small patches of weathered

loess, containing calcareous concretions, or *loess kindchen,* lie within the slumped masses, below the general level of the plain, and the loess may, therefore, be younger than the till and gravel.

The till and gravel of Prairie Divide represent a widespread glaciation. Their weathered condition and their topographic position above the valleys containing the more recent glacial deposits testify to the relatively great age of this glacial stage. The locality is also far to the east of the most advanced position of the later glacial moraines, a fact which suggests a very much larger glacier than any formed in later time. This glaciation is here named the "Prairie Divide stage" and is probably correlative with the Cerro glaciation of the San Juan Mountains (Atwood and Mather, 1932).

OTHER POSSIBLE PRE-WISCONSIN GLACIATIONS

No evidence of a glacial stage comparable in size and position with the Durango stage of the San Juan Mountains (Atwood and Mather, 1932) has been discovered in the Cache la Poudre drainage basin. The Durango stage is, however, assigned somewhat doubtfully to the Iowan, here termed "Wisconsin I." Further study may indicate that the pre-Home glacial substage, to be described, is correlative with the Durango glaciation, but at present it can be suggested only as a possibility.

At several places in the Colorado Front Range, Ray has observed glacial till which is best attributed to the Durango stage. A detailed description of these deposits will appear in a forthcoming paper on the glaciation of the Southern Rocky Mountains.

THE CANYON-CUTTING CYCLE

During the long interval which separated the earlier from the Wisconsin glaciations of the Colorado Front Range, streams entrenched themselves deeply in both the mountains and the plains. This period of erosion, called the "canyon-cutting cycle" (Van Tuyl and Lovering, 1935), marks the time immediately preceding the Wisconsin glaciation. Remnants of the materials deposited by the two earlier glacial epochs were dissected during this stage. The general relationship between this period of stream entrenchment and the stages of glaciation characteristic of other mountains of the Cordilleran region appears to hold throughout this area.

The Cache la Poudre Valley within the mountains is deeply entrenched, set within an older, broader valley that is now represented by prominent rock spurs. The lower, or downstream part of the

3

canyon is typically unglaciated and **V**-shaped. The upper, or upstream part, is characterized by a **U**-shaped profile and also by erratics, roche moutonnée surfaces, small hanging valleys, and isolated patches of glacial debris. Transition between the two valley types occurs at Home Post Office (fig. 1), at an elevation of about 7,600 feet. Here, a terminal moraine stretches almost completely across the valley, rising about 135 feet above the level of the river, which flows through a notch between the moraine and the bedrock of the northern valley wall (pl. 4).

HOME, AND A POSSIBLE EARLIER, GLACIAL SUBSTAGE

The moraine at Home Post Office (pl. 4) presents a rounded and mature aspect. However, careful examination shows that this smooth topography is the result of a covering of wind-blown sand. On the upstream side of the moraine the cover is thicker and more effectively conceals the bouldery surface than on the downstream side. Scattered over the surface of the moraine are ventifacts, or stones that are polished, grooved, and faceted by wind-blown sand. Obviously, sand is not now moving down the valley, and one must suppose that the small dunes behind the moraine and the sand that cut the ventifacts were moved by winds that swept down the valley over the glacier. The sand was derived from the surface of the glacier and from the barren outwash plains. Such cold glacial winds moving down the valley under gravitational forces are characteristic of the valleys below existing glaciers in Alaska, where dunes are being built from sands of the outwash plains. Similar dunes are built and stones are being cut on the outwash plains of Greenland (Hobbs, 1931). In the Sierra Nevada of California, Blackwelder (1929) has described a boulder carved during the Pleistocene by wind-blown sand.

Roche moutonnée surfaces adjacent to the moraine are fresh and show glacial striae at localities that are protected by a slight covering of glacial drift or of vegetation, whereas unprotected surfaces lack polish or striations. When fully exposed to weathering at the present rate in these altitudes, the bedrock is so easily weathered that it is unable to retain the marks of glaciation for any great length of time. For the foregoing reasons, the apparent lack of glaciated surfaces related to the moraine does not necessarily imply great age. Observation throughout the Colorado Front Range indicates that glaciated surfaces, related to moraines otherwise similar, are, unless protected, preserved only on unusually durable rock.

The question has been raised whether the moraine at Home, and the glacial substage named for it (Louis L. Ray, 1938), are possibly

of pre-Wisconsin age. The subdued topography of the moraine might, as some writers hold for other localities, be attributed to long weathering of the surface during and after the retreat of the ice. One needs to guard against attempting to date glacial stages on the basis of a subdued topography of the moraines, for in this case it is not due to processes of weathering and denudation, but to wind deposition. Considering the topographic position of these moraines within the present canyons, the relatively slight degree of chemical alteration and slight compaction of the till, and the lack of deep gullying on the Home moraine, or on similar moraines in other areas of the Front Range, the writers believe that it is impossible to assign an age older than Wisconsin. General indications are, however, that these moraines were not made by the first advance of the valley glaciers in Wisconsin time, that is, the Iowan substage or Wisconsin I, but were made by the second advance of the Wisconsin time, or Wisconsin II.

Several lines of evidence point to the possibility of a pre-Home glacial substage, the terminal moraine of which, now removed by erosion, was almost coincident with the Home moraine. As shown in plate 5, figure 1, several large erratic boulders lie well above the valley floor on the south valley wall, immediately upstream from the Home moraine. Inasmuch as they lie above the reconstructed grade of the ice which built the Home moraine, it is conceivable, but highly improbable, that they were brought to position during that period of glaciation. A somewhat larger glacier, which extended perhaps as much as half a mile farther down the valley, would have had a height sufficient to have deposited the boulders in their present position. For the half mile below the Home moraine, the canyon is open and U-shaped, and is then sharply constricted into a V-shaped gorge. This narrow, winding gorge shows no signs of glaciation.

The most definite evidences for a pre-Home period of glaciation are small lateral valleys, some 250 feet or more above the present level of the valley floor (C and D in fig. 8). Compared to the lower and similar valleys at B (fig. 8) they are relatively old, as the walls are much weathered and the floors are filled with talus. These valleys were formed by streams which drained the lateral margin of a valley glacier too high to have been related to the Home moraine. These small valleys are similar in origin to the lateral channel that lies about 140 feet below (B in fig. 8). This valley has straight clean walls and is so youthful that it seems to have been deserted only yesterday by the waters which carved it. It stands at an elevation so low that it must have been cut by streams draining the lateral margin of the ice as it began to retreat from the Home moraine. It is not necessary to

postulate a long period for the formation of these little canyons, for similar straight-walled cuts in bedrock form in short periods of years along the lateral margins of the present retreating glaciers of Alaska (Louis L. Ray, 1935, pp. 304-307).

Further evidence for this postulated pre-Home glacier exists in the lower canyon in bodies of gravel which stand too high above the river to be remnants of the valley train produced by the Home glaciation (see pp. 42 and 43).

The positions of erratics near the Home moraine, the high lateral canyon, and the pre-Home valley train all seem to indicate that a valley glacier, whose terminal moraine has been completely removed, once existed. On the basis of this evidence, the writers postulate
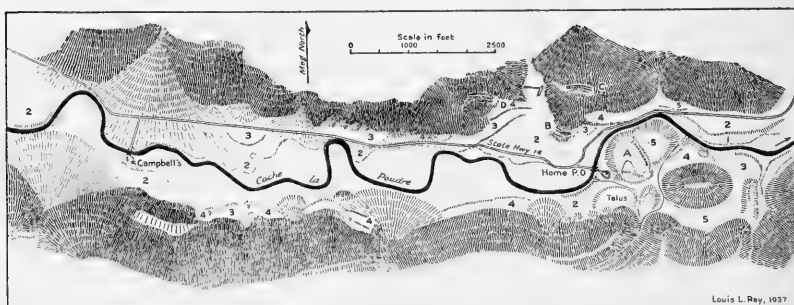
FIG. 8.—Sketch map of the Cache la Poudre Valley at Home Post Office, showing: A, Home moraine; B, low lateral bedrock gorge; C and D, high lateral bedrock gorge; and terraces of 5 groups, numbered from youngest and lowest to oldest and highest.

a pre-Home glacial substage of Wisconsin I (Iowan) age, but they have refrained from giving it a name.

The evidence in the Cache la Poudre Canyon for this pre-Home substage is not as complete as is desirable, but in adjacent regions there is additional evidence, of which the most important may come from the region immediately south of the Rocky Mountain National Park, near Ward (Wahlstrom, 1939). Furthermore, Ray has examined the moraines of the Libbey Creek Valley in the Medicine Bow Mountains, described by W. W. Atwood, Jr. (1937).

The moraine near Libbey Lodge, which has been attributed to the Wisconsin by Atwood, has an aspect similar to the Home moraine. It is here correlated with the Home moraine and attributed to Wisconsin II. The lowest moraines in the inner valley, between Libbey Lodge and Centennial, which Atwood considers pre-Wisconsin, have a somewhat older aspect, and may be correlated with the pre-Home,

or Wisconsin I. It is possible that Atwood uses "pre-Wisconsin" in the sense of Iowan of the older terminology. Under present usage Iowan is equivalent to Wisconsin I, in which case, his correlation is equivalent to the one here given.

The Home substage of glaciation is represented by the moraine, already described, and the outwash plain, or valley train, preserved as terrace remnants approximately 90 feet high, immediately below the moraine. Small lateral channels cut as sharp boxlike canyons 15 feet wide and 20 feet deep in bedrock occur on the north side of the valley, 60 feet above the stream grade (fig. 8, B). Patches of striated and wind-polished rock occur on the flats above and on the upper parts of the walls of these little canyons. That these surfaces are yet unharmed by weathering is in itself evidence of the relatively recent date of the Home substage, which is considered to be of Wisconsin II age.

CORRAL CREEK SUBSTAGE OF GLACIATION

Following the retreat of the glaciers of the Home substage, or their possible complete disappearance, there was another glacial advance. The ice streams were relatively small and reached down to and formed moraines at elevations ranging from 9,100 to 10,100 feet in the valley of the Cache la Poudre River and its major tributaries. Instead of a single moraine, there are moraines in the tributary canyons that lie from 1,500 to 2,500 feet above the moraine at Home. The ice tongues that built these moraines descended from cirques down the valleys of Long Draw, Trap, Joe Wright, and Corral Creeks, and also in the so-called main valley of the Cache la Poudre.

The best-developed moraines lie in the valley of Corral Creek, whose name has been given to this substage (Louis L. Ray, 1938). Here the ice tongue extended approximately 4 miles from the cirque, to an altitude of 10,100 feet (pl. 5, fig. 2). The moraine stretches almost completely across the valley, except for a small notch along the south side, through which Corral Creek flows to join the Cache la Poudre River about a mile and a half downstream. Up the valley, there are small patches of glacial debris, scattered along the broad, flat valley floor, deposited during retreatal pauses of the Corral Creek glacier as it receded from the advanced position marked by the main moraine.

In general, the surface of the Corral Creek moraine is subdued and has an aspect similar to that of the Home moraine, except for the presence of a greater number of large scattered boulders. A care-

ful search revealed a few stones that are slightly wind-cut, but none show faceting. Little wind-blown sand is present. The feeble wind action thus indicated, implies a less active and less prolonged period of wind activity than occurred during the Home substage.

The ice mass moving down Joe Wright Creek (Home Quadrangle) was larger than those in the other valleys, for it was fed from a larger area of accumulation below the high summits of the Medicine Bow Mountains to the west. This glacier moved into the Laramie River valley, where it built a moraine; it also pushed a lateral tongue down the valley containing the present Chambers Lake. This tongue reached into the drainage of the Cache la Poudre River, where a morainic complex was built that now dams the valley and holds in the waters of Chambers Lake. Recently an artificial dam has been constructed on one of these retreatal moraines to raise the level of the water of the natural lake. Light blue-gray bouldery till, with unweathered blocks of all the local rock types, is revealed in a road-cut through this moraine. This till is so fresh as to be in marked contrast to the highly weathered till of the Prairie Divide stage. It is also slightly fresher than the till of the Home moraine.

The difference in the amount of weathering of the till, the distinct topographic position of the moraines in the valleys, and the widespread distribution of comparable moraines lead to the conclusion that these features indicate a glacial substage separate and distinct from the Home substage. According to the terminology used, this is considered to be Wisconsin III.

LONG DRAW SUBSTAGE OF GLACIATION

Immediately below the cirques at the heads of Corral Creek and Long Draw Creek there are evidences of an ice advance. Below the cirque of Corral Creek there is an outwash plain, pitted with kettle holes (pl. 6, fig. 1)—material evidence for a slight readvance of glacial ice, although in this valley no terminal moraine was developed (Louis L. Ray, 1938). Remarkably fresh, soled and striated boulders occur in this outwash.

Below the lip of the nearby cirque of Long Draw Creek (secs. 7 and 17, T. 6 N., R. 75 W.) there is a low and poorly developed moraine, apparently contemporaneous in age with the pitted outwash plain of Corral Creek. These features are the youngest and least altered glacial deposits in the drainage basin of the Cache la Poudre River.

The name "Long Draw" is here given this glacial substage. Examination of many cirques throughout the Colorado Front Range in-

dicates that this slight advance is general and not peculiar to the mountains of northern Colorado. It is thus a definite stage of re-advance of the ice or a prolonged halt in the final recession. In the nomenclature here adopted it is considered to be Wisconsin IV.

PROTALUS SUBSTAGE

In the Corral Creek cirque lies a great ridge of angular debris, which from a distance appears to be a glacial moraine (pl. 6, fig. 2). However, close inspection of the mass of poorly sorted and angular boulders gives no indication of till or outwash of glacial origin. This ridge is a protalus rampart (Bryan, 1934), built of blocks from the cirque head wall, loosened by intense frost action, or nivation, and accumulated by rolling down over the snowbanks that once occupied the cirque. Because at the present time snowbanks of such size no longer form in the Corral Creek drainage, this is an ancient feature. Similar snowbanks and small ice masses, over which rocks roll each spring, still exist in the nearby cirques of the higher parts of the Colorado Front Range, in Rocky Mountain National Park. During the last general period of refrigeration the snowbanks, or perhaps the last remnant of glacial ice, still lingered in this shady head-wall region of the Corral Creek cirque, its record surviving only as this rampart of rough blocks.

Protalus ramparts may be seen in numerous cirques of the Colorado Front Range. They thus indicate a period, or periods, of slightly colder climate preceding that of the present.

SUMMARY

In the Cache la Poudre drainage basin there is direct evidence for an early Pleistocene glacial stage, the Prairie Divide, which is probably correlative with the Cerro stage of the San Juan Mountains. In the inner canyon of the Cache la Poudre there are terminal moraines of three substages of the Wisconsin: Home, Corral Creek, and Long Draw. Less conclusive evidence indicates that there is also a pre-Home substage of the Wisconsin. A protalus rampart in the valley of Corral Creek records a recent period of refrigeration, too feeble to produce ice tongues which moved from the cirques.

Similar features in other parts of the Southern Rocky Mountains are proof of a similar number of advances of the ice. On this account, the stages differentiated locally may be considered the records of climatic changes that were of wide extent and were not unique to the Cache la Poudre Canyon.

TERRACES OF THE CACHE LA POUDRE CANYON

THE CANYON

The Cache la Poudre River, with its headwaters at the Continental Divide, flows for about 58 miles through a deep, and in places narrow, mountain canyon. Near the village of Bellvue, the river leaves the canyon through a gateway in the hogback ridges and begins a meandering course across the Colorado Piedmont (fig. 1). The fall of the canyon floor between the headwaters and the mouth is more than 5,500 feet, so that the average gradient of the stream is approximately 95 feet per mile, or 1°. This is in marked contrast to the gradient of the stream between the mouth of the canyon and the confluence with the South Platte River, near Greeley, where the gradient is only about 10 feet per mile.

The inner canyon of the Cache la Poudre River, here discussed, is a deeply entrenched valley, cut below an older broad valley during the last great period of stream entrenchment, the canyon-cutting cycle. Numerous high bedrock spurs rising to more or less accordant heights indicate former positions of the valley floor, at each of which the stream excavated a valley broader than the present inner canyon. These stages are of the same age as the pediments of the lower country and therefore are not directly pertinent to the problem of the age of the terraces. The glaciers of the Wisconsin stage and the associated low gravel terraces are confined to the present inner canyon and are definitely younger than the rock spurs.

The inner canyon of the Cache la Poudre River is separable into two divisions, the glaciated portion above Home Post Office, and the unglaciated portion below. The gradient of the canyon floor in the unglaciated portion averages about 80 feet per mile, in the glaciated about 115 feet per mile. These, however, are by no means smooth gradients, for an examination of the river profile (fig. 9) shows a series of breaks in gradient. There are about seven such well-defined breaks in both the glaciated and the unglaciated stretches of this inner canyon. They occur mainly at constrictions, or "narrows," where the bedrock is resistant to weathering and the river has been able to cut only deep, narrow gorges. Where the bedrock is easily weathered, the valley has been widened, the walls are less steep and more widely separated, and the river gradient is smooth.

Large talus cones, developed along the valley walls of the inner canyon, indicate the great amount of weathering which has occurred since the canyon-cutting cycle of late Pleistocene time. The larger of the cones are below the lower limit of glaciation, at Home Post Office.
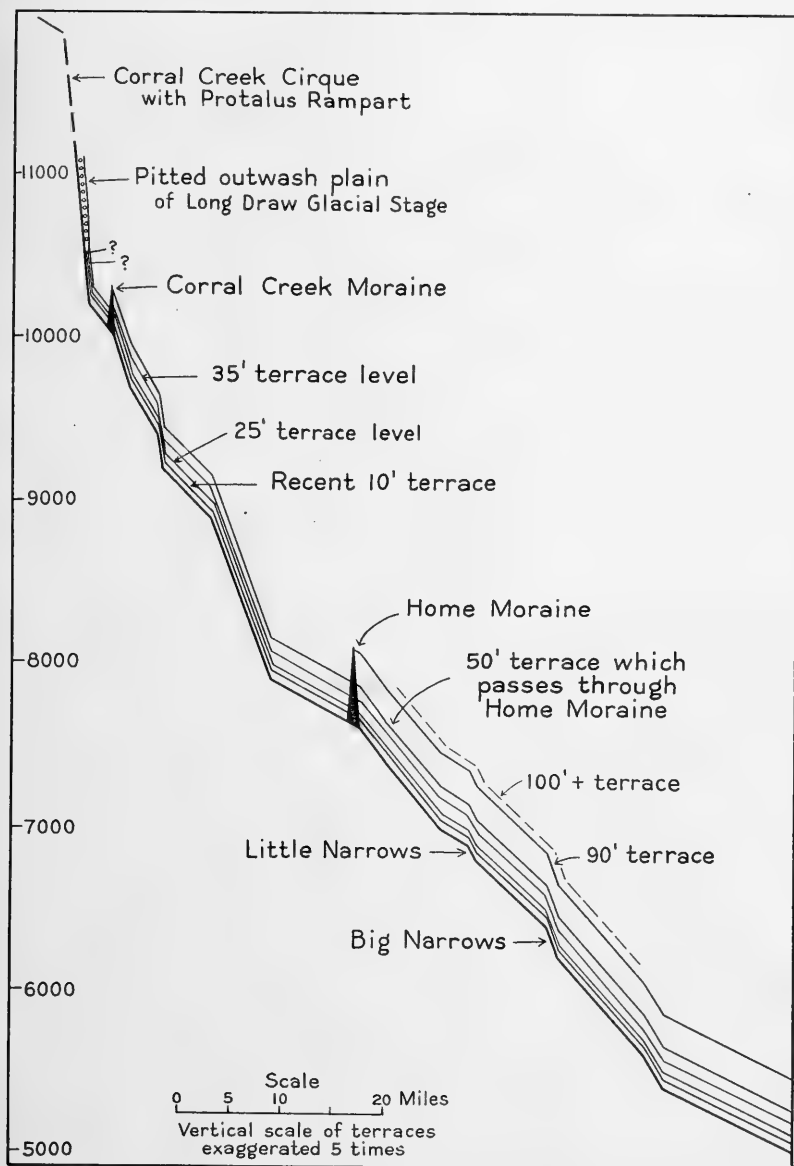
Fig. 9.—Generalized profile of the Cache la Poudre Canyon, showing terrace sequence and relation to glacial features.

Smaller, but well-developed cones occur in the glaciated portion of the canyon, indicating the rapidity with which some of the bedrock of pre-Cambrian granite and schist has disintegrated. The angular debris of these talus cones, in places roughly stratified by gravitational sorting, is displayed where the cones are dissected or cut by the river. A large part of the talus material consists of fine sand and comminuted rock, the products of local weathering and frost action.

NATURE OF VALLEY TRAINS

It is a recognized feature of mountain glaciation that glacier-fed streams carry large quantities of detritus. Because of their overloaded condition they build up their gradients and submerge the lower parts of the valleys with sand and gravel. These bodies of alluvium are termed the valley train, and by continued deposition they increase in height until the glacier has reached its point of maximum extension. On the retreat of the glacier the increased melt-water drainage removes much of the gravel and sand composing the valley train. Thus, in any one period of valley glaciation the lower portions of the valley, below the ice terminus, are first filled with fluvio-glacial debris and are thereafter, on the retreat of the glacier, more or less thoroughly cleared of this material. The pebbles and cobbles of the valley trains do not necessarily show the typical pentagonal, soled, and striated glacial form (Wentworth, 1936), but may be well rounded and give no evidence of their glacial origin (Louis L. Ray, 1935, p. 314). The remnants thus resemble any ordinary terrace recording a period of alluviation followed by a period of dissection.

Glaciers of three, possibly four, Wisconsin substages moved down the Cache la Poudre Canyon after the entrenchment of the stream during the canyon-cutting cycle. During each stage of glaciation a valley train was produced which was partially removed during the retreat of the ice from its position of maximum advance, marked by a terminal moraine. Each successive period of glaciation, each less extensive than the previous one, should be indicated by a terrace. The amount of glacial filling of the valley, and therefore the height of the valley train, is directly proportional to the size of the glaciation. Not only do greater glaciations endure longer, but the ice mass is larger and extends farther downstream. The terraces of the Cache la Poudre are not only comparable in number to the number of stages of valley glaciation, but certain terraces can be traced directly into terminal moraines. The details of the terraces and the methods by which they are correlated with each other and with the glacial stages are here set forth.

METHODS OF TERRACE STUDY

In the canyon of the Cache la Poudre River the terraces are common topographic features, in places rising steplike one above the other, or occurring as individual broad gravel flats, or as isolated gravel patches caught in minor inequalities of the rocky valley walls. Dissected remnants of these valley trains extend far beyond the canyon mouth and may be traced as terraces on the Cache la Poudre and South Platte Rivers. In order to carry the late glacial chronology of the mountains (see pp. 30-35) into the Colorado Piedmont, it is necessary to correlate the gravel terraces of the canyon with the terraces of the South Platte River.

A small portion of the valley train of the Home stage of glaciation is preserved as a terrace remnant, about 90 feet in height above the river, in front of and adjoining the Home moraine (figs. 8 and 10). Similarly, a remnant of the next lower valley train, whose height is about 50 feet above the stream, is preserved in front of the moraines of the Corral Creek stage, at Chambers Lake. Here, the river has exposed good sections through the moraines and the associated valley train. The transition may be followed between the heterogeneous materials of the morainal till to the roughly stratified fluvio-glacial materials of the valley train.

Downstream from the moraines, the terrace remnants have been mapped, and as shown in figures 9 and 10, they fall into a series of definite and correlatable groups. The highest of the terrace levels are the most poorly preserved, and stretches of several miles separate the remnants. The youngest terraces, on the other hand, are so numerous and have elevations above the level of the river which are so nearly the same that they may be separated into groups only with the greatest difficulty.

The elevations of terrace remnants above the river grade were carefully measured by hand level, from the water level at the time of measurement to the upper surface of the terrace. As the river grade is the only practical base from which to measure the height of the terraces, its fluctuation in water level from day to day, or hour to hour, is important. As the flow of the river, and thus its level, is regulated for irrigation, these fluctuations are highly irregular. A fluctuation of 2 feet, caused by the opening of water storage reservoirs near the headwaters of the river, does not materially effect the measurements of the higher terraces that lie from 35 to 90 feet above the grade of the river. However, the elevation of the low terraces, closely spaced and lying from 6 to 12 feet above the river, are seri-
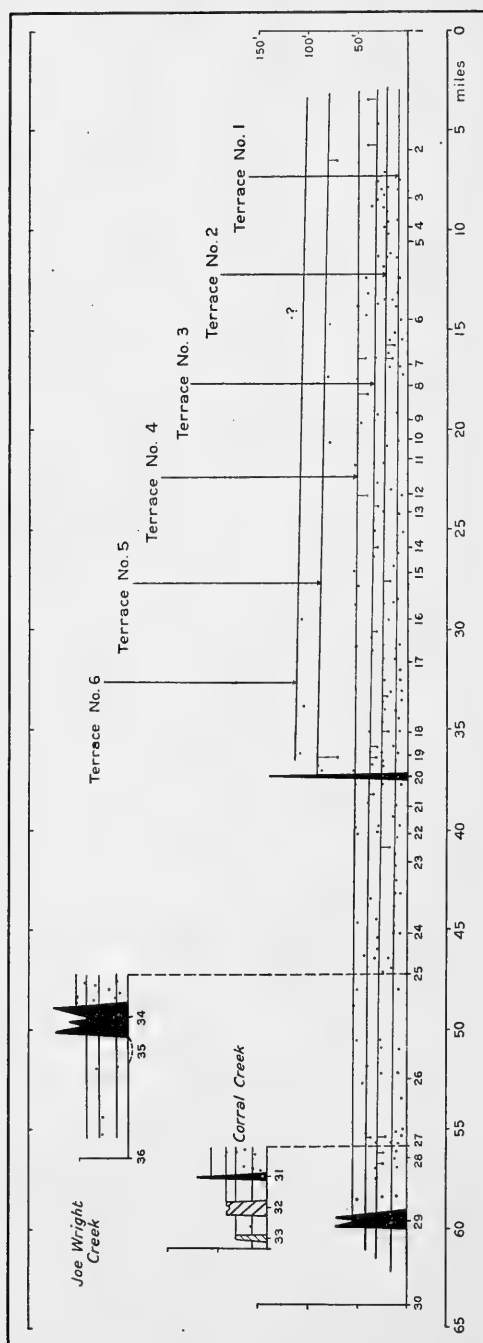
FIG. 10.—Diagram showing distribution of the terrace remnants and their height relative to the Cache la Poudre River within the canyon. Moraines shown in solid black; pitted outwash plain and protalus rampart of Corral Creek cirque are cross ruled.

ously affected. This inherent inaccuracy in the data makes a correct interpretation of the lower terraces difficult. Further inaccuracies arise because the original upper surface of many terrace remnants is not too well defined, and because many of the higher terrace remnants are covered with talus. Many terraces have been so eroded that their remnants show no trace of the original upper surface. Here, only the present upper limit of river-borne gravel can be measured and the original elevation of the terrace level must be estimated. In the correlation of terrace remnants it must be kept in mind that the remnants of a single terrace do not necessarily stand at the same elevation above the present stream. In any one portion of the canyon the present stream does not necessarily follow the course of the depositing stream and may intersect the originally graded plain of deposition at various angles, and thus the stream grade may be at unequal distances below the terrace grade. Furthermore, the heavily laden and swiftly flowing streams which deposited the valley trains probably did not produce plains of absolutely smooth slope. By reason of their great activity, they filled the valley to a general level, but there were doubtless many slight irregularities. Also, with the first and probably hesitating retreat of the glaciers, there were developed slight irregularities on the surface of the valley trains by the erosive action of the melt-water streams (Louis L. Ray, 1935, pp. 303-307).

All terrace remnants are slightly higher above the present stream grade at their points of origin, that is, at the terminal moraines of the glacial stages to which they are related, than at the mouth of the canyon. Profiles of the terraces show that there is a general tendency for the terrace remnants to converge toward the mouth of the canyon. This convergence is continued away from the mountain front, so that in eastern Colorado the higher terraces have been lowered, and several of the lower terraces have completely disappeared.

The lower terraces of the Cache la Poudre Canyon cannot be related to definite periods of ice advance from the cirques, but by analogy with the strictly glacial terraces are held to represent a local refrigeration. Each terrace is considered the representative of a period of increased cold and intensified frost action in the cirque areas of the higher mountains. The overloaded streams built up their grade and laid down a gravel plain similar to, but smaller than, the valley trains of the earlier glacial substages. With each change to a warmer and drier climate, these gravel flats were dissected.

The original correlation of the terraces of the Cache la Poudre Canyon was worked out on a large chart on which the river profile

was plotted with a horizontal scale of 2 inches to the mile, and the terrace remnants shown in pattern on a vertical scale of 2 inches to 100 feet. A similar chart on a much reduced scale, with the Cache la Poudre represented as horizontal (fig. 10), shows much of the data of the original profile.

There are in the canyon of the Cache la Poudre River six or more terraces, the oldest related to the oldest glaciation of the inner canyon, the youngest, which may represent several small terraces, so poorly defined that it is thought inadvisable to attempt a separation, but to classify these remnants as a single terrace of postglacial age. For descriptive purposes, the terraces are numbered from 6 to 1, from oldest and highest to youngest and lowest. They are discussed in this order.

TERRACE NO. 6

The highest and oldest terrace of the Cache la Poudre Canyon, No. 6, is poorly defined, and its presence is based on evidence which has resulted from the detailed study of the valley. The first line of evidence has been described on pages 31 to 33, where it has been pointed out that there is reason to believe there was a glacial advance in the inner canyon before the Home substage. This earliest glacier advanced only a few hundred feet farther down the canyon than the glacier of the Home substage, and almost all traces of it have been removed by subsequent erosion. However, this glacier must have built a valley train similar to, and slightly higher than, that of the later Home substage. During the long interstadial period between the recession of this ice and the advance of the ice of the Home substage, erosion removed almost all of the old valley train.

At three localities small gravel patches were found above the general level of the next lower, or No. 5, terrace. These form the second line of evidence for the No. 6 terrace. At Indian Meadows, near Dadd's Gulch, where the valley of the Cache la Poudre is unusually wide, a single gravel remnant lies on the south valley wall, 108 feet above the stream. Although this gravel may represent material brought down into the main valley by a tributary stream and deposited on the 90-foot terrace, No. 5, it may also represent either an unusually high remnant of the No. 5 terrace, or, what seems most reasonable, a remnant of a higher terrace, correlative with the pre-Home glaciation.

Another similar remnant of weathered gravel is perched on the north valley wall, about 4.5 miles upstream, at an elevation about 105 feet above the stream. At Hewlett Gulch another small body of

gravel is located on the valley wall some 120 feet above the stream. These gravel remnants lead to the belief that the No. 6 terrace once existed at a grade somewhat more than 100 feet above the present river, and that this terrace is correlative with the pre-Home substage of glaciation. In the lower canyon and in the Colorado Piedmont this terrace has either been removed or obscured and merged with the slightly lower No. 5 terrace.

The third line of evidence pointing to a No. 6 terrace rests on the low, gravel-capped, bedrock spurs, which represent the floor of the Cache la Poudre Canyon belonging to the pre-Home substage of glaciation. Below the moraine at Home there are numerous patches of gravel resting on low bedrock benches, which average about 20 to 30 feet above the present stream grade. These bedrock benches are the remnants of the surface on which the debris from the retreating glacier was deposited to form the No. 6 terrace. During the long interstadial period between the pre-Home and Home glaciations the gravel of the No. 6 terrace was largely removed and the bedrock valley floor dissected. During the later glaciations the old channel has been buried and reexcavated several times. In the canyon, above the Home moraine, no remnants of these bedrock spurs have been found, for they have been removed by the ice of the Home substage or transformed into roche moutonnée surfaces. The fact that the moraine at Home appears to rest upon the present bedrock floor of the canyon indicates that the spurs are not to be associated with the Home substage, but with the previous substage of glaciation.

TERRACE NO. 5

Approximately 90 feet above the Cache la Poudre River there is a gravel terrace, the remnants of which are found only in the valley below the moraine at Home. This terrace is held to be correlative with the advance of the ice of the Home substage and is the oldest and highest terrace in the canyon which may be directly correlated with a terminal moraine. Adjacent to the Home moraine there are several terrace remnants which lie at elevations of 85 to 90 feet above the level of the stream (fig. 8, see terrace marked "5"). A terrace of small extent, near the moraine, with an elevation of 70 feet is considered a reduced portion of the No. 5.

Ten miles downstream, at Stevens Gulch, another large remnant is preserved at 78± feet above the river. Here the general level of the terrace is somewhat lower than 90 feet. This height, however, may not be a great deviation from the actual level of the old surface of the terrace along the axis of the river at this point. Six miles farther

east, at Hewlett Gulch, an outcrop of gravel at 80 feet above the stream, indicates a continuation of this terrace.

At the mouth of the Cache la Poudre Canyon, near the Greeley Waterworks Dam, gravel occurs on the valley wall at an elevation of 72 feet above the stream. The upper surface of the deposit has been removed by erosion, but the height of the deposit is such that this is assuredly a remnant of either the No. 5 terrace or the possible older terrace, referred to previously as No. 6.

The gravel of the No. 5 terrace is not definitely distinguishable from that of the younger terraces. It is well rounded, decreasing in size from a maximum of 4 feet near the moraine to 10 to 12 inches at the mouth of the canyon. It is only slightly iron-stained, and not deeply weathered.

The small number of remnants may be considered a challenge to their correlation as a terrace. However, when one considers that no remnants have been found in the canyon above the Home moraine, whereas the remnants at the moraine are definite and obviously related to the moraine, there seems to be no good reason for doubting its validity as the representative of an ancient valley train, contemporaneous with the ice that formed the Home moraine. The upper surface of the No. 5 terrace is considered, therefore, to mark the maximum filling of the valley by debris at the time of the Wisconsin II glaciation.

<div align="center">TERRACE NO. 4</div>

Below the No. 5 terrace a better-preserved series of terrace remnants lie at elevations of approximately 50 feet above the grade of the river. In the lower portion of the canyon, from the mouth to the North Fork, terrace remnants at elevations accordant with this height are lacking. However, near the mouth of the canyon, on the plains near Bellvue, there are terraces with elevations of 40 feet and more, which are considered the equivalent of the 50-foot terrace of the canyon. Above the North Fork the terrace remnants are more closely spaced and better preserved, with especially good examples at Eggers, Elkhorn Creek, Stove Prairie Landing, and Roaring Creek (fig. 10). At Home, below the moraine, there is a remnant of this terrace at approximately 54 feet above the river. Upstream from the Home moraine are a series of remnants lying at the 50-foot level (figs. 8 and 10). Two and a half miles above the Home moraine, at Roaring Creek, there are well-preserved flats at 50 and 52 feet above the river. The gravel of these remnants is comparatively fresh and unaltered.

In the Middle Fork of the Cache la Poudre River, below Chambers Lake, the No. 4 terrace can be carried directly to the moraines of the Corral Creek stage of glaciation, by a series of accordant terrace remnants, which impinge on the moraines. Here a gradual transition can be traced from the till of the moraines to the stratified and sorted material of the terrace. At this point (fig. 10) there is definite evidence that the No. 4 terrace is the product of the Corral Creek glacial substage, just as the No. 5 is held to be the product of the Home glacial substage.

Following the main Cache la Poudre River toward its headwaters at Milner Pass, the No. 4 terrace may be traced to the moraines of the Corral Creek stage at Chapin Creek. They may also be followed up the tributary Corral Creek to the moraine which marks the type locality of the Corral Creek glacial substage. No traces of gravel have been found above these moraines which can be interpreted as belonging to this terrace. The direct merging of the terrace gravel with the moraines, together with the lack of remnants above the moraines, and the relatively large number and close spacing of remnants at approximately 50 feet above the river throughout the Cache la Poudre Canyon, make this terrace the most valid and give certainty to its date as the valley train of the Wisconsin III glacial substage.

TERRACE NO. 3

In the upper canyon of the Cache la Poudre River, remnants of the No. 3 terrace [6] occur at an elevation about 40 feet above river grade and in the lower canyon at 30 feet. The decrease in height is marked, but the remnants are more numerous and more closely spaced than the remnants of the higher and older terraces. At Home, where the terrace passes through the moraine, remnants are broad and easily recognizable (fig. 8).

Especially well preserved are those terrace remnants which lie below the moraines of the Corral Creek substage of glaciation. Above these moraines are numerous low and modified remnants of glacial debris, probably retreatal phases in the recession of the ice from the Corral Creek moraines, perhaps remnants of this terrace. Adequate information is lacking which would definitely prove a direct relationship between the No. 3 terrace and the Long Draw moraines, for in no place can the terrace gravel be found in contact with the moraine, as in the case of terraces Nos. 4 and 5. However, one may assume

---

[6] Referred to in preliminary report as 25-foot terrace and incorrectly correlated with 30-foot, or Kersey terrace (Bryan, 1937).

4

that a genetic relationship with the Long Draw moraines is not only reasonable, but most probable.

The second terrace occurs about 18 to 25 feet above the grade of the river. It is represented by more remnants of greater lineal extent than any of the older terraces. Between the mouth of the canyon and the mouth of the North Fork, a long series of terrace remnants lie between 18 and 22 feet above the river. Below the Home moraine is another long expanse of this terrace at 24 feet. Below the Corral Creek moraine is a large and well-preserved terrace remnant with a surface several acres in extent, at an elevation approximately 25 feet above the stream. Similar remnants below the mouth of Long Draw Creek also have a height approximately 25 feet above the stream. There can be no mistaking the identification of this terrace from place to place, and its validity as a stage in the history of the valley cannot be doubted.

No correlation is observed between this terrace and any glacial stage in the Cache la Poudre Canyon. It is, however, tentatively thought to be correlative with a climatic change, probably the one which produced the protalus rampart of the Corral Creek cirque. Such a correlation seems justified on the basis of the terrace and the glacial sequence, but it must await further proof.

Throughout the length of the Cache la Poudre Canyon and its major tributaries there are low gravel terraces, ranging from 6 to 12 feet above the level of the stream. It is possible that these may represent two or more distinct terrace levels, but no attempt has been made at subdivision, and they have been grouped into a single terrace, the average height of which appears to be about 8 feet above the stream. Because of the constant fluctuation of the river and the small height of these terrace remnants, the percentage error in the determination of their height is relatively great, as has been previously noted. A bouldery terrace, the general height of which is not more than 6 feet above the stream, may be the result of unusual floods of the river in the present cycle. Terrace remnants at heights near 12 feet probably represent an older terrace, not now subject to the stream floods. The term "No. 1 terrace" is thus a blanket name for low terraces of relatively recent origin. On the plains, immediately east

of the mountain front, these low terraces are indistinguishable and have apparently merged with the flood plain of the river.

CORRELATION OF THE TERRACES OF THE CACHE LA POUDRE CANYON WITH THOSE OF THE COLORADO PIEDMONT

It has been shown that the terrace remnants of the Cache la Poudre Canyon fall into six grade lines, the elevations of which above river grade near their points of origin are: 100+, 90, 50, 35, 25, and 6-12 feet. There is doubt as to the validity of the 100(+)-foot terrace, and the lowest terrace level is probably a complex of recent terraces.

Except for the 90-foot terrace gravel, which is slightly iron-stained, no substantial difference can be detected in the amount of weathering of the gravel of the lower terraces, for all the terraces are sufficiently young so that the lapse of time has been too small to produce significant weathering.

The terraces of the Cache la Poudre Canyon are separated from the older broad valley levels of the Cache la Poudre River by a period of canyon-cutting. It has been shown that the alluvial terraces of the Cache la Poudre and South Platte Rivers in the Colorado Piedmont are also separated from the older and higher gravel-capped pediments by a period of stream incision. This period of incision by the streams was simultaneous in the mountains and the plains. Terraces of the inner canyon are found to be correlative with the alluvial terraces of the Cache la Poudre and South Platte Valleys.

Near the mountain front no terrace remnants have been found which can be definitely correlated with the No. 5 and older (?) terrace of the mountain canyon. However, a definite correlation is possible between the 50-foot terrace of the canyon, the No. 4, and a terrace level of about 40 feet elevation above the Cache la Poudre River on its south bank near the village of Bellvue. This terrace may be followed more or less continuously from the vicinity of Bellvue, down the Cache la Poudre River to the South Platte River, where it is seen to be correlative with the Kersey terrace (pp. 25, 26). The lower Kuner terrace is held to be the correlative of the 35-foot terrace of the mountain canyon.

If the No. 4 terrace of the mountain canyon is the correlative of the Kersey terrace, it seems only reasonable to believe that the No. 5 terrace, of Home age, is correlative with the Pleasant Valley terrace. If the No. 6 terrace actually exists, it is doubtful if remnants of it could be distinguished from the Pleasant Valley terrace away from the mountain front. Thus, it would seem that the following

correlation may be made between the glacial substages of the mountain canyon, the terraces of the canyon, and the terraces of the Colorado Piedmont:

Glacial substage	Canyon terraces	Colorado Piedmont terraces
Pre-Home substage (Wisconsin I ?)	No. 6, or 100(+)-foot terrace	?
Home substage (Wisconsin II)	No. 5, or 90-foot terrace	Pleasant Valley
Corral Creek substage (Wisconsin III)	No. 4, or 50-foot terrace	Kersey
Long Draw substage (Wisconsin IV)	No. 3, or 35-foot terrace	Kuner
Protalus rampart (Wisconsin V)	No. 2, or 25-foot terrace	River flood plain
Post-glacial or Recent	No. 1, or 6- to 12-foot terrace	

FOLSOM SITES IN THE REGION AND THEIR BEARING ON THE GEOLOGIC AGE OF THE CULTURE

Two other sites in the Colorado Piedmont shed light on the antiquity of the Lindenmeier site. One of these has been described by Figgins (1933), the other has been mentioned before only briefly (Bryan, 1937).

Near Dent, a siding on the Union Pacific Railroad, sec. 13, T. 4 N., R. 67 W. (Greeley Quadrangle), large bones were discovered and reported to Father Conrad Bilgery, S. J., who, on excavation, found an artifact associated with the bones. Father Bilgery enlisted the aid of J. D. Figgins, at that time associated with the Denver Museum, who continued excavations at this site, uncovering a large number of mammoth skeletons, mostly those of young females, and another artifact, associated with the bones. These artifacts are spear points of the type usually referred to as "Folsomoid" and are similar to points which have been found recently at the Lindenmeier site. Thus, the Lindenmeier and Dent sites appear to have been contemporary.

The bones and artifacts at Dent occur on the inner edge of a gravel terrace adjacent to the valley wall and near the top of the gravel. In this vicinity, the top of the terrace lies approximately 27 feet above the flood plain of the South Platte River. The site is accordant in height and has gravel similar to other terraces in this

part of the South Platte Valley which are considered remnants of the Kersey terrace.

Near the village of Kersey Mr. Forrest Powars and his son Wayne discovered Folsom points of the normal type, together with numerous snub-nosed scrapers, in a sandy field. The sand is wind-blown and rises as a dune in a gentle slope from the level of the Kersey terrace to a height of approximately 30 feet (pl. 3, fig. 1). The artifacts are found in the upper few feet of the sand over a large area, but there is no definite culture layer. However, as the artifacts are similar to those found at the Lindenmeier site, it appears that they are contemporaneous and that the Folsom hunters camped on a sand dune blown from the flood plain of the river when the river flowed at the level of the Kersey terrace.

The Dent and Kersey sites confirm the correlation between the culture layer of the little valley at Lindenmeier, and the Kersey terrace, and show that the Lindenmeier site was not the only camping place of the Folsom hunters in the Colorado Piedmont. All three localities were occupied after the upper surface of the terrace had been built and before its dissection. In other words, the sites were occupied either during the maximum advance of the Corral Creek glaciers, or soon after the beginning of their retreat. The finds at Dent are in the upper part of the terrace, just how near the top is not quite clear from Figgins' (1933) account. At Kersey the artifacts do not occur on the terrace but slightly above the level of the terrace in dune sand. Probably the river periodically washed the foot of the slope and periodically shifted, leaving a barren channel. From this channel the sand was blown onto the terrace. Since the artifacts are not buried more than 2 to 3 feet, we are led to believe that the camp must have been occupied at the end of the period of building of the sand dunes or at the time when the glaciers of the Corral Creek substage had already reached their maximum.

GLACIATION AS A CHRONOLOGY

The culture layer at the Lindenmeier site is of the same age as the Kersey terrace and cannot have continued to form for any great length of time after dissection of the terrace began. The Kersey terrace is the equivalent of the No. 4 terrace in the Cache la Poudre Canyon, which in turn is the outwash train of the Corral Creek glaciers. The Lindenmeier culture layer is thus of the same age as a glacial substage which is presumably Wisconsin III. In order to complete the history of the Lindenmeier site and to provide as close an approximation to a date as is possible in the present state

of knowledge, it is necessary to relate the glacial substages in the Cache la Poudre Canyon with the North American and European glacial chronologies. Such a correlation involves grave possibilities of error in itself, and further, the standard chronologies are not without flaw. These difficulties are here set forth in considerable detail.

The discovery on all the continents and many oceanic islands of deposits laid down by glaciers that have since disappeared, long ago raised the problem of the contemporaneity of these ancient glaciers. With the further discovery that glaciation is multiple, that at nearly every place two or more, usually four, major glacial advances have occurred, and that these advances of the ice were separated from one another by intervening times of warm climate comparable to, or warmer than, the present, the problem was intensified.

All phases of this problem have been recently summarized by Daly (1934, pp. 30-41). He has ably marshaled all the evidence on several lines of analysis, which indicates contemporaneity. The viewpoint is not universally accepted (Lugn, 1935, p. 31) and is not at present subject to absolute proof. Nevertheless, the authors hold with Daly that the major advances of the great continental ice sheets were broadly contemporaneous. It does not necessarily follow that the climaxes of these ice advances were precisely synchronous. In fact, American geologists have brought forward proof of a progressive shift from east to west of the main ice center throughout the last, or Wisconsin, glacial stage. Yet, as methods of obtaining data are imperfect and subject to error, there is an unavoidable tendency to use any ascertained date as a world-wide reference point.

In the following discussion, the European chronology will be first considered, and thereafter the North American. The two will then, so far as possible, be brought together and a correlation made with the glacial stages of the Cache la Poudre Canyon.

THE EUROPEAN GLACIAL CHRONOLOGY

THE MAJOR ICE ADVANCES

Investigation of the European glacial deposits and related interglacial sedimentary beds has been very active in the past 20 years. At present so many new facts and conclusions are being published that no general statement on chronology can be made that will meet the views of all authorities.

The concept that the glacial period was marked by four great glacial advances, separated by periods of mild climates as warm as, or warmer than, the present, is generally accepted. This is the

familiar subdivision current for many years, which is set forth in table 1. There is, however, a growing tendency to consider that each of the glacial stages was multiple and consisted of at least two ice advances, separated by a definite interstadial period of ameliorated climate. This viewpoint is supported by many new field facts relating to the terrace systems, loesses, and pollen-bearing beds of the periglacial region of South Germany. The recognition of weathering zones as evidences of the milder climates of interglacial, or interstadial periods, has been of great importance. Also, the study of pollen and other vegetative remains has led to the recognition of many beds deposited in climates as warm as, or warmer than, the present and therefore of interglacial or interstadial age. This recognition of

TABLE I.—*General Glacial Chronologies*

Climatic expression	Alpine area	North German Plain	Continental glaciers of the United States
4th glacial	Würm	Weichsel (incl. Warthe)	Wisconsin (incl. Iowan)
3rd interglacial		"Saw"	Sangamon
3rd glacial	Riss	Saale	Illinoisan
2nd interglacial		"Es"	Yarmouth
2nd glacial	Mindel	Elster	Kansan
1st interglacial		?	Aftonian
1st glacial	Günz	?	Nebraskan (Jerseyan)

a general climatic rhythm has forced the conclusion that many of the glacial stages heretofore recognized are complex rather than simple.

This viewpoint is also influenced by the calculations of Milankovitch (1930), whose astronomical theory calls for double or triple cold stages at each glaciation. Direct correlation of glacial substages with the cold periods indicated by the astronomical theory is advocated.most strongly by Soergel (1925), and this system has been admirably set forth, with disarming ingenuity and candor, by Zeuner (1935).

It is obvious that the older subdivisions are of less importance in this study. Our concern lies with the subdivisions of the last glacial stage and of the long interval of transition to the present. In this field there is at present no agreement among European students, except that the efforts of each of them makes more apparent than

before the complexities of the advance and the final retreat of the last ice. If we accept, for example, the views of Gams (1938), it is necessary to recognize 10 periods of ice advance during the last, or Wisconsin, glaciation. Each ice advance is separated from the other by a time of slightly ameliorated climate, and many of these intervals are recognized by deposits containing pollen, diatoms, and other plant remains, or by fossil animals, either vertebrate or invertebrate.

There are many obvious difficulties in the geologic proof that a certain fossiliferous bed is older than the deposits of one ice advance and younger than the deposits of another. Yet each of these numerous, widely scattered deposits records an ameliorated climate, a definite retreatal or interstadial, or interglacial time. Each is an entity whose presence must be considered. Each represents a period of more genial climate which must be fitted into the pattern of successive climatic fluctuations. The continued study of these deposits and the discovery of new deposits forces reinterpretations of the strictly glacial deposits of the times of ice advance. Whether or not the 10 periods advocated by Gams survive the test of continued study of the problem, it seems evident that the events of the last ice age have been oversimplified. The effect of these newer viewpoints on the interpretation of work in geochronology will be further emphasized.

LATE-GLACIAL CHRONOLOGY

To the classic researches of Gerard De Geer we owe the invention of the method of geochronology by the counting of varves. These double layers of silt and clay silt are the unique deposits of glacier-fed lakes. The silt is deposited by the agitated waters of summer, the clay by the still waters of the ice-locked winter season. The measurement and correlation of such layers required much labor, skill, and judgment, and the scientific world has accorded generous credit to De Geer and his Swedish coworkers for their great accomplishment. The same tribute must be paid to Sauramo and other Finnish geologists for their extension of the chronology to the east side of the Baltic Sea, and also to Antevs, who has found in North America varve sequences exceeding those of Europe in the total number of years by more than three times.

The method, however, is limited by the existence of suitable clays. Not every retreating ice front acted as a dam to hold in a proglacial lake in whose bed varves were deposited. The same ice front that at times during the retreat laid down varves, at other times lay on

the land, or was flanked by salt water, so that no varves were formed. Thus, however perfect the chronology attained by varve counts, it is applicable to a part of late glacial time only. The gaps in the chronology must be filled by estimations of one type or another. If this discussion appears to emphasize these gaps, the reason lies in the present-day tendency to a glib assumption that the dates of many Pleistocene events have been fixed. They have been merely estimated. Skill, judgment, and the result of much labor by many earnest geologists have all contributed to these estimates. Nevertheless, as shown herein, the results have no binding authority and are at best provisional.

As shown in figure 11, which is based on the map by Antevs (1928), the last ice in North Europe deposited three morainal systems, the Fläming, the Brandenburg, and the Pomeranian (Great Baltic). Each moraine represents an advance of the Scandinavian ice sheet after a period of retreat. Opinions differ as to the length of these periods of ameliorated climate and their value in classification, but all students admit that in each interval the ice retreated and the climatic conditions may have been somewhat similar to those of the present.

The question of the age of the Fläming moraine, which is also termed the Warthe glacial stage, is still the subject of much discussion (see the brief review by Gams, 1938). Some hold that this stage is the Third Glacial, or the equivalent of the Riss stage; others, an advance just before the last ice age; still others consider it the first forward shove of the last ice. Thus, the Warthe occupies in Germany much the place of the Iowan of North America. If, following the recent decision on the Iowan (Kay, 1931, and Leighton, 1931), the Warthe is considered as an early substage of the last ice age, it may be the first major advance. It would then fit into the scheme of Soergel (1937) and Zeuner (1935). This placing of the Iowan as the first Wisconsin advance in North America is not, however, universally accepted by American geologists (Leverett, 1939, and Lugn, 1935).

The Brandenburg moraine, or Weichsel substage, is generally believed to represent the climax of the last ice age, except by De Geer, who has always believed that the Pomeranian should hold that honor. Most students now consider that the last glaciation had three maxima, the Warthe, Weichsel, and Pomeranian substages, the designations of which they frequently abbreviate to W1, W2, and W3.

The recessional stages during the retreat from the Pomeranian moraine are shown in figure 11, after Antevs (1928), whose names
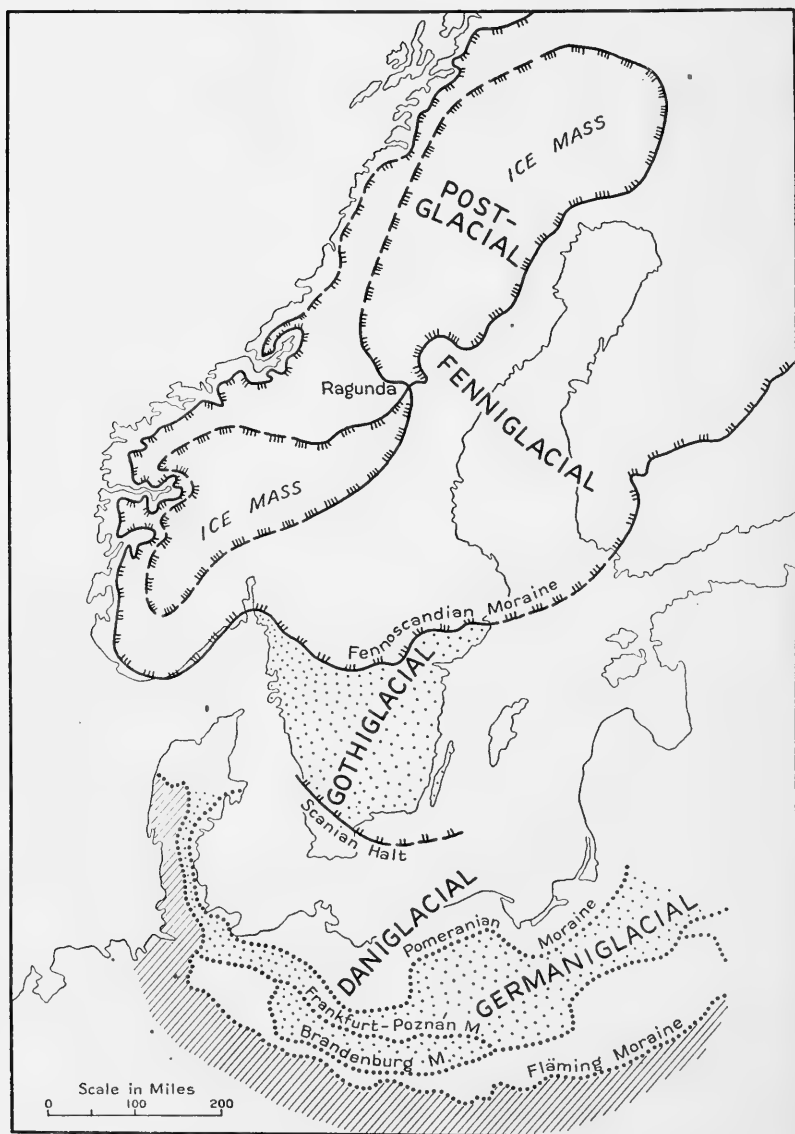
FIG. 11.—Map showing moraines of the last glaciation and retreatal substages on Europe. Modified from Antevs.

for the intervals of retreat are followed. The advances and retreats involved in these time intervals, as interpreted from Antevs' text (1928), are shown diagrammatically in figure 12.

No diagram is attempted for the retreat from the Fläming moraine, although it may have been, and according to Soergel (1937) was, quite complete between the Fläming (Warthe) advance and the Brandenburg (Weichsel) advance. Similarly, the retreat from the Brandenburg (Weichsel) and readvance to the Frankfurt-Poznán moraine is shown by but two simple lines. It is probable that this is an oversimplification and our ignorance of the facts prevents
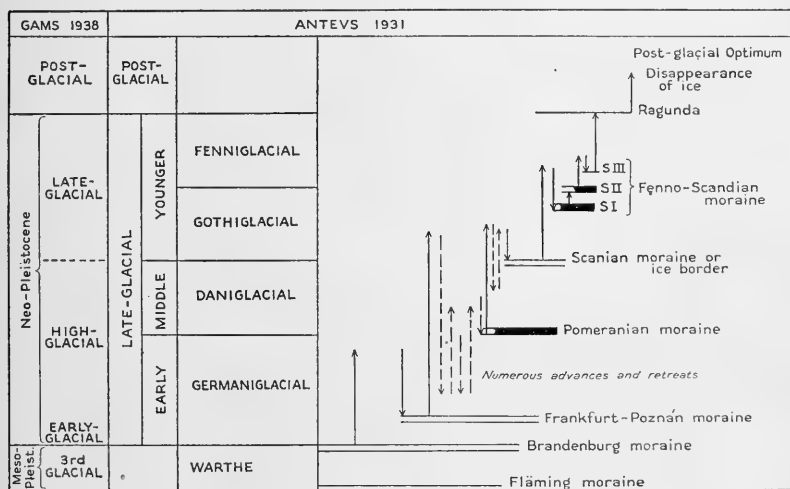
Fig. 12.—Subdivisions of the late glacial period, with diagrammatic representation of the several advances and retreats of the ice. Moraines shown in black are included in the next youngest substage.

representation of the complications that probably exist. From the Frankfurt-Poznán moraine to the Pomeranian moraine, there were numerous advances and retreats. These movements were complicated, and the data are obscure, but the problems involved are being vigorously attacked by Richter (1937) and others.

The time of final dissipation of the ice began with the retreat from the Pomeranian moraine. To some geologists this marks the end of the glacial period, a viewpoint set forth by Gams (1938), whose classification is shown on the left in figure 12. From the standpoint of geochronology, this interval of time is the most important, as parts of it have been measured by the methods of varve-counting.

Figures 11 and 12 show that this interval is divided into the Dani-glacial, Gothiglacial, Fenniglacial, and Post-glacial substages, which are separated from each other by halts in the ice retreat or by other ascertainable events. The relation of the intervals to the moraines varies. Thus, the time necessary to form the Pomeranian moraine is held to be part of the Germaniglacial, and the time interval of the Scanian halt is assigned to the Gothiglacial. The first two halts of the Fennoscandian (Salpausselkä) moraine are also part of the Gothi-glacial. The third halt falls in the Fenniglacial. This third period of recession is terminated by the bipartition of the ice mass at Ragunda.

The length of these time intervals is only partly known. The Post-glacial time interval is estimated to be 8,700 years on the basis of varve counts and estimations by Lidén (1913), which are only in part published. The extensive work of De Geer (1926 and earlier papers) on varves yields a complete sequence of 1,703 years for the Fenni-glacial, which is partly confirmed by the work of Sauramo (1928). For the Gothiglacial there is no complete varve count. Sauramo has shown that the Salpausselkä double moraine required 670 years, and he has counted 1,250 or more annual varves in Finland, south of this moraine. De Geer (1926) has long sequences of varves in south Sweden, but the time interval of the Gothiglacial is nevertheless an estimate. Some authors give 2,500 and some 3,000 years for this interval.

De Geer (1926) identifies one of the moraines of southwestern Sweden, apparently somewhat beyond the position of the Scanian halt, as the equivalent of the Pomeranian. He gives, without full ex-planation, a date of 18,000 years ago for this supposed Scanian-Pomeranian moraine. This figure has been accepted without much question by many coworkers. Antevs (1928, pp. 157-160) discusses the problems involved at considerable length, and following several Danish geologists and his own field work, considers that the Pomer-anian is represented by the East Jylland moraine of Denmark. Thus, he makes clear the existence of the time interval that he calls the Daniglacial. He estimates this time interval to be 10,000 to 15,000 years long, but there is no continuous varve count to support this estimate. The moraines in southern Scania, which De Geer (1926, pl. 3) correlated with the Great Baltic, or Pomeranian, are, as Antevs points out, much younger. De Geer (1926) gives an estimate of 9,500 years as the time interval between these moraines and the Ragunda bipartition of the Fennoscandian ice mass.

The length of the Gothiglacial, that is the interval from the halt in Scania (southern Sweden) to the end of the halt at the Fenno-

scandian moraine, is not distinctly set forth by De Geer, but Antevs (1928, p. 160) estimates it to be 2,000 years, plus the 670 years required for the building of the moraine which was determined by Sauramo in Finland. Sauramo (1928) states that he counted 2,400 varves in southern Finland, which together with the time interval of 670 years for the moraine would give 3,000+ years for the length of the Gothiglacial—a figure which is accepted by many authors.

The length of the Fenniglacial interval is given by De Geer (1926) as 1,703 years. This interval includes the period of retreat of the ice from the moraine to its bipartition at Ragunda. Sauramo (1928) has found this interval to be almost the same length as that given by

TABLE 2.—*Correlation of Swedish and Finnish Geochronologies, According to Sauramo*

Years of Swedish chronology	Years of Finnish chronology	Intervals between correlated positions in ice retreat in Sweden	Intervals between correlated positions in ice retreat in Finland
(at Ragunda) 0	Not determined		
— 500	1,100		
		600	580
—1,100	520		
		400	420
—1,500	100		
		100	100
—1,600	0		
		400	500
—2,000	— 500		
		1,000	900
—3,000	—1,400		
	Totals	2,500	2,500

De Geer. The relations, shown in his figures 18 and 19, reconcile the two chronologies. The data of these figures are here reproduced in table 2. It will be noted that there are discrepancies, but that for the whole period counted, they balance out. However, for the Fenniglacial, De Geer gives 1,703 years, and Sauramo 1,100 years of his chronology, plus 500 years of the Swedish, or only 1,600 years.

The complex glacial chronologies of Europe have been reviewed and an attempt made to clarify the European picture of the recession of the ice of the last glaciation. It has been shown also that the length of the Late-glacial period of Europe is largely estimated and that the varve counts give sure information for only a small part of the total time involved.

GEOCHRONOLOGY IN NORTH AMERICA

METHODS AND RESULTS

Estimates of the time back to the last ice age were made long ago, using many geologic methods, of which the most important was the rate of recession of Niagara Falls (for history, see Taylor, 1913). This method is supplemented by Antevs (1922, 1928, and 1931), who has combined with it the system of geochronology introduced by De Geer. There are, however, many difficulties in providing a complete chronology, primarily because varved clays are lacking in suitable positions, and secondarily because the details of geologic history are not wholly known, as much of the work in glacial geology has been in the nature of reconnaissance. Compared to the intensive study of the Pleistocene in the Baltic region, work in North America has lagged in the past 30 years. The material which follows is largely a critical review of the long-continued work of Antevs, who has summed up the difficulties in the introductory paragraphs of his paper of 1936.

As shown in figure 13, Antevs measured 5,500 varves from New Haven to Hartford, 4,100 from Hartford to St. Johnsbury, and 2,000 from Montreal River to a point north of Cochrane, Ontario. These intervals in the retreat are the only ones for which there is a geochronological dating, and the other intervals must be estimated in one way or another.

The interval from Stony Lake to Mattawa is estimated on the rate of retreat of Niagara Falls. Obviously this estimate is based on the present rate of retreat which has been established by historical means and by certain assumptions as to variations of the rate of recession in the past by reason of variations in the quantity of water pouring over the falls. However much care may have been put in such an estimate, it has sources of error quite different in amount and in kind from the errors of varve measurement.

In table 3, the several retreatal substages, their distances from each other, and various measurements and estimates of the time intervals are shown. In columns 2 and 5 are shown Antevs' estimates of 1928 and 1931, the differences in which will be discussed. Considering column 2 first, the elapsed time from the present to the moraine at St. Johnsbury, Vt., is $15,000+x+y+z$, in which x and y are unmeasured intervals of the retreat, and z is the time required for the melting of the ice from a point near Cochrane to the present. The period of ice retreat from Montreal River to a point beyond Cochrane is 2,000 years, represented by varves counted by Antevs. The period of retreat from Stony Lake to Mattawa is based on the

EXPLANATION

① Time interval probably equal to Peorian; length unknown.

② Varves counted = 5500 years, but not applicable to retreat of ice from W2.

③ Based on counted varves.

④ Time interval estimated on recession of Niagara Falls.

⑤ Based on counted varves.

⑥ Z years = time of melting of ice remnant + U or time after disappearance of ice.
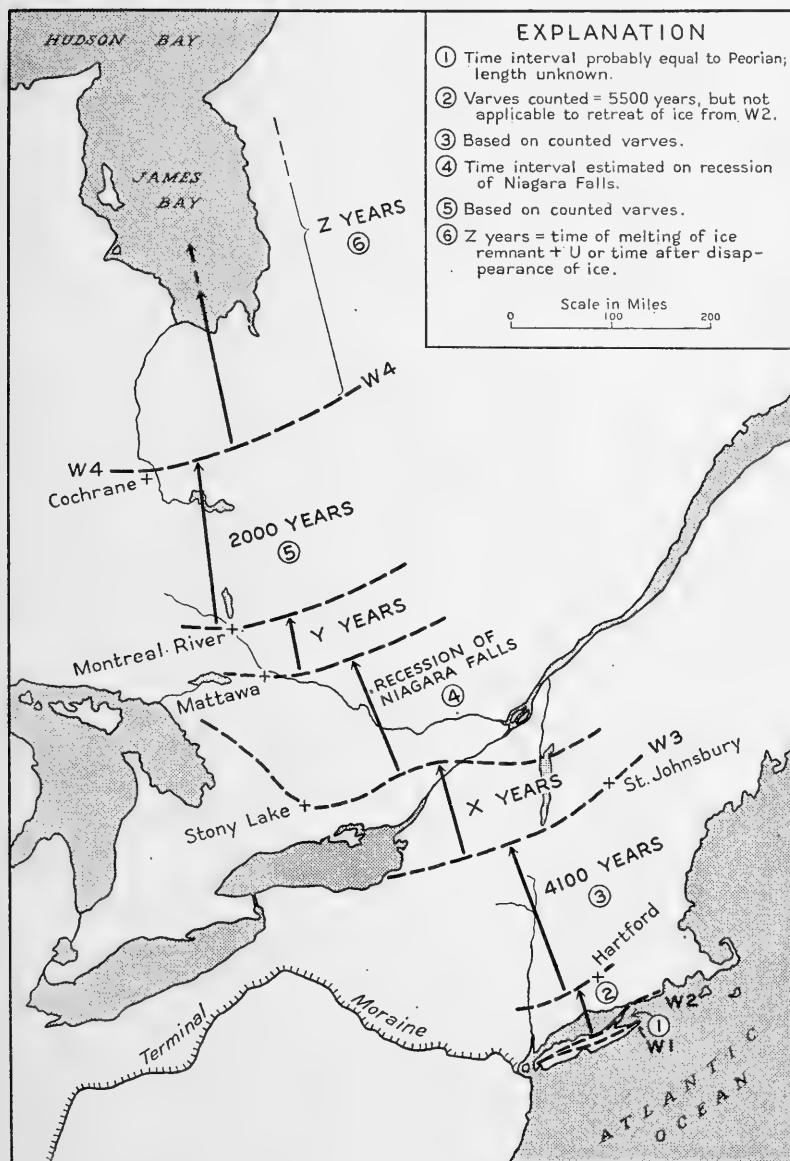
Fig. 13.—Map showing retreat of the continental glacier in eastern North America. Modified from Antevs.

TABLE 3.—*Recession of the Last Ice According to Various Estimates*

	Distance (km.)	Time (years) Antevs, 1928	Rate of recession (yrs./km.)	First recalculation (Bryan)	Time (years) Antevs, 1931	Rate of recession (yrs./km.)	Second recalculation (Bryan)
	1	2	3	4	5	6	7
Present time to time of disappearance of ice in James Bay plus retreat from Cochrane	1,500—1,800	5	(0.7)	1,000+u	2,000+ and u=7,000	(1.25)	1,875+u $\left\{\begin{array}{l}200?\\725\end{array}\right.$
Cochrane from Montreal River	1,200	2,000	1.4	2,000	6,000	1.25	1,500
Montreal River from Mattawa	850	y	(1.4)	1,200		1.10	1,000
Mattawa from Stony Lake	750	13,000	17.3	13,000	10,000±		
Stony Lake from St. Johnsbury	525	x	(17.3)	9,000			10,000
St. Johnsbury from Hartford	298	4,100	13.0	4,100	4,100	13.00	4,100
Hartford from Harbor Hill	95	5,500	(13.0)	1,235+800= 2,035	5,500	(13.00)	2,000
Harbor Hill from Ronkonkoma	0-20	2,000			2,000		
Elapsed time to St. Johnsbury = Pomeranian		15,000+x+y= 16,400—17,400 +z		26,200+u	25,000±		15,300+ u=22,300
to Harbor Hill = Brandenburg				32,300+u			21,400+ u=28,400
to Ronkonkoma = Iowan = Warthe		28,000+z= 37,000		?	36,500		?

recession of Niagara Falls. The missing intervals x and y are estimated at 1,400 to 2,400 years, but no information is given as to how the estimate is made, except general statements that ice retreat was rapid in these areas.

The interval St. Johnsbury to Hartford was determined by Antevs (1922) by numerous measurements of varves in the gray clays of this area. Here there is a long sequence of 4,100 varves, representing the same number of years. The interval of retreat from Hartford to New Haven is represented by 5,500 varves, measured by Antevs in the red clays of this area, largely before 1922. This sequence has been correlated with a similar sequence in the Hudson Valley. However, it has never been demonstrated that these varves represent the retreat of the last ice. In the New Haven area the top of the clay beds is always eroded and the base largely unknown. At Berlin, Conn., according to observations by Bryan, the clay is overlain by a solifluction layer, or warp, and the upper part of the clay is so weathered as to destroy its original lamination. It is also cut by joints and cracks containing colloidal clay. This zone has the character of the lower part of the B-horizon of a weathering profile. It thus appears that the clay has been exposed and has suffered from weathering in a climate at least as genial as the present. At a later period the upper part of the soil zone was carried away and a warp developed in a climate of Arctic severity. Leached clay is reported by Antevs at station 129 (Middletown, Conn.) and station 134 (Berlin, Conn.), and various kinds of disturbed or changed clay at nearly every locality from New Haven to Berlin (Antevs, 1928, pp. 184-188). On this evidence, it appears that the red clays of the Berlin area are older than the last interglacial, or interstadial, and may belong to an earlier ice advance. Under such an interpretation, varve measurements of these clays cannot be used in this sequence.

There is a further difficulty to be faced. Antevs follows all earlier authorities in assuming that the two moraines on Long Island were the result of a single period of ice advance. If this were true, they represent a forward movement to the southerly moraine, or Ronkonkoma, a slight retreat and a forward movement to the Harbor Hill moraine. Such a history might require only a short time. For the time interval, Antevs allows 2,000 years. Recent work in southern New England (Bryan, 1936) indicates that the Watch Hill moraine of Rhode Island, which is the equivalent of the Harbor Hill moraine of Long Island, differs markedly from the moraine of Cape Cod and Marthas Vineyard in its preservation of glacial topography and in its state of weathering. The moraines of Cape Cod and Marthas

Vineyard lack true morainic topography and are formed of sand and till stained by limonite. The relatively fresh aspect of the topography and the till of the Watch Hill moraine are proof of its relative youth and indicate that it is separated from the earlier moraines by a long interval of time. Between the fresh Harbor Hill moraine and the older Ronkonkoma this difference is implied in the descriptions by Fuller (1914). His statements make it impossible to believe that these two moraines record merely a pulsation at the maximum advance of the ice. They must be separated from each other by an interstadial, if not an interglacial period of weathering. Insofar as this point of view has merit, it is a mistake to attempt to carry a reckoning of the chronology, based on varve counts, to the southerly, or Ronkonkoma moraine.

The Ronkonkoma moraine of Long Island and the moraines of the Cape Cod region are largely formed of folded and deformed members of the Manhasset beds, which according to both Fuller, and Woodworth and Wigglesworth (1934) are next younger than the Gardners clay and are the equivalents of the Illinoisan, or Third Glacial. Recently MacClintock and Richards (1936) have correlated the Gardners clay with the Cape May formation of New Jersey, which is of Sangamon or third interglacial age. Thus, the Manhasset would fall in the earlier part of the Fourth Glacial, or Wisconsin. This correlation is accepted by Flint (1935) and applied specifically to Marthas Vineyard and Cape Cod. With such a correlation the ridges, known as moraines, are obviously due to shove by the same ice sheet which deposited the materials. How great an interval there may have been between the glacial deposition of the Manhasset and its deformation by ice shove there is at present no means of estimating.

The moraines of southeastern Massachusetts and their correlative, the Ronkonkoma of Long Island, under this interpretation probably represent the earliest Wisconsin substage, or Iowan. The interval of time between their formation and that of the Harbor Hill-Watch Hill moraine is long and corresponds to the Peorian. After withdrawal of the ice there was a considerable period of weathering. This interstadial is possibly not completely represented in the famous Farm Creek section of Illinois (Leighton, 1926). However, observations by Leighton and Bryan in 1938 indicate that additional information on the climate of the interstadial may be obtained by further study of this locality.

As the warmer climate of the Peorian interstadial deteriorated, a forward movement of the ice toward the position of the Harbor

Hill moraine occurred. How long a time interval is required for forward movement over the area from which the Ronkonkoma (Iowan) ice had retreated is unknown. It may easily be that the red varved clays of the New Haven-Berlin area were laid down during the recession of the Ronkonkoma ice. If so, they were weathered in the interstadial and overridden by the Harbor Hill ice. The confused varves at the top and the evidences of disturbance described by Antevs (1922 and 1928) may be due to this overriding and also to erosion and solifluction during the retreat from the Harbor Hill moraine.

In the calculation of elapsed time, Antevs, in his book of 1928, is conservative. For the St. Johnsbury substage he estimates the intervals x and y (fig. 13) as 1,400 to 2,400 years, without stating the evidence on which these figures are based. Using this estimate he has obtained for the age of the St. Johnsbury substage a total of 16,400 to 17,400 years, plus z, or the time of final melting north of Cochrane, Ontario. His figure for the moraines of Long Island is $26,600 + x + y$, or 28,000 to 29,000 years.

However, it is possible to make a re-estimate, using a somewhat arbitrary system. If the assumption is made that the rate of retreat in the intervals unrepresented by measurements of varves, or by other chronological data, is similar to that of adjacent intervals that are so represented, a total as shown in column 4, table 3, can be computed. Here the Ronkonkoma to Harbor Hill interval is omitted as being impossible to estimate. Harbor Hill to Hartford is estimated by applying the rate of recession of the next northerly interval to the distance which is 95 km., or 1,235 years, and arbitrarily adding 800 years as the estimated time that the ice lingered on the moraine. Thus, the interval becomes 2,000 years. The intervals x and y are estimated by applying the rates of the next intervals, yielding 9,000 and 1,200 years respectively. The interval z, or 1,500 miles, is arbitrarily given a rate of retreat half that of the previous interval, and thus yields 1,000+ years. However, there remains a time interval u, from the last disappearance of the ice in Labrador to the present. The totals for St. Johnsbury and for Harbor Hill by this method are $26,200 + u$ and $32,300 + u$, and thus considerably higher than Antevs' totals.

In 1931 Antevs again published on this subject, recording new observations in Canada. His statements in this paper are in many instances cryptic, and it may be that he is here misinterpreted. He redivides the retreat and uses arbitrarily stated figures. Thus, the interval z, the Post-glacial, is given as 9,000 years. This figure is ex-

plained in part on his pages 18 and 19, where detailed studies of the advance and retreat of the ice near Cochrane are discussed. The retreat from Montreal River extended 50 miles north of Cochrane, and is measured by varves totaling 2,025 years. The ice then readvanced to the Cochrane moraine in a time interval estimated as 200 years. These years are excluded from the Post-glacial, which consists of the retreat from Cochrane and the final disappearance of the ice, including the remaining time to the present. The Post-glacial is preceded by the slight advance of the ice to Cochrane which is presumably correlatable with a climatic shift toward the cold, such as was coincident with the last Yoldia Sea in Europe. The 9,000 years of Antevs' estimate is thus obviously the 8,700+ of the European reckoning of the age of this last Yoldia Sea.

The retreat from Mattawa to Cochrane is estimated (column 5, table 3) at 6,000 years. This figure includes the 2,025 plus 200 years of the Montreal River-Cochrane interval previously explained, plus 3,775 years arbitrarily assigned to the interval y.

The interval from St. Johnsbury to Mattawa is reduced to 10,000± years as a result of recent work on Niagara Gorge by Johnston (1928) and further study by Antevs. However, a critical reading of the discussion (Antevs, 1931, pp. 20-24) does not reveal the number of years actually assigned to the interval Stony Lake-Mattawa, the time of Lake Algonquin, or any comment on the interval x (St. Johnsbury-Stony Lake). It appears, therefore, that this new estimate is largely arbitrary, although it may be very nearly correct and is certainly entitled to much respect by reason of Antevs' long consideration of the problem of the age of Lake Algonquin.

The estimate of the time involved in the interval St. Johnsbury to Ronkonkoma is unrevised and not discussed, so that its existence must be inferred from the statements that the total time to the "New York Moraine," or Ronkonkoma, is 36,500 years.

The foregoing estimate has been recalculated in column 7, in the same fashion as the previous estimate is revised in column 4 of table 3. Accepting Antevs' new estimate of 1,500 years for the Montreal River-Cochrane interval, and 725 years for the retreat beyond Cochrane, with 200 years as necessary for the readvance to Cochrane, the Post-glacial retreat from Cochrane at the rate for the previous interval will be 1,875 years. There is also the unknown length of time from the final disappearance of the ice to the present, or u. Antevs (1931, pp. 18-19) also gives a new estimate for the Mattawa-Montreal River interval as 1,000 years. Such a time interval could be arrived at by assuming any reasonable rate, and differs by only 200

years from the estimate of column 4, table 3. It may then be accepted. Also, Antevs' (1931) new estimate of 10,000 years for the two intervals St. Johnsbury-Stony Lake and Stony Lake-Mattawa, although not completely supported, is doubtless not far from correct. Furthermore, using the varves as a basis, the Hartford-St. Johnsbury interval is 4,100 years. If then the same approach is used for the retreat from the Harbor Hill moraine, the interval is 2,000 years. By this substitution the time back to the St. Johnsbury is $15,300 + u$, and to the Harbor Hill $21,400 + u$. If the interval u is 7,000 years, as assumed by Antevs, these intervals become 22,300 and 28,400 years.

VALIDITY OF RESULTS

The foregoing tedious survey reveals a closet of dry bones in which there survives an emaciated creature having promise for the future, but of little value in the battle of the moment. Estimates have been piled on estimates and added to known time intervals, none too securely tied to the geologic framework. If, however, the data of table 3 are examined, the elapsed time to the St. Johnsbury moraine has been estimated by somewhat different methods to give the following results: $16,400 + z = 25,400$; $26,200 + u = 33,200$; $25,000 \pm$; and 22,300 years. All these figures are of the same order of magnitude. The Harbor Hill, or what many consider essentially the equivalent, the Ronkonkoma moraine, is estimated with the following results: $28,000 + z = 37,000$; 32,300; 36,500; and 28,400 years. These estimates are also of the same magnitude. It is true, of course, that all these figures are influenced by the same basic measurements and estimates and particularly by the assumption of 9,000 years for the length of Post-glacial time. This figure is obviously based on the rather well-supported European figure, but as it has a magnitude of more than a third, or, at least, a fourth of any one of the totals, it affects them all to an almost dominating extent.

Antevs' estimates of 1931 are obviously improved over those of 1928, largely because of the adjustment for the life of Lake Algonquin, based on the history of Niagara Falls. His estimate of $25,000 \pm$ years for the St. Johnsbury moraine may eventually be reduced, as indicated in column 7, table 3. The reduction, however, will probably be moderate. Similarly, his estimate of the date, and the time elapsed since the New York (Ronkonkoma) moraine, which he assumed to be the climax of the Wisconsin, is more likely to apply to the Harbor Hill moraine. It may be that the reduction of this interval to 28,400 years may prove to be too conservative. To the extent that

the calculations of Milankovitch are accepted, any of these estimates of the age of the Harbor Hill moraine are much too low.

If now the dates of the North American chronology are compared with those of Europe, the concordance is not as close as could be desired. It is obvious that none of the existing estimates, however ingenious, or based on however much laborious work, is as yet so close to the true figure that it must be accepted without qualification. In truth, we have not yet arrived at such a stage in research on the Pleistocene. The figures given are merely first approximations which with some confidence may be considered of the correct order of magnitude. They may be received with respect, but the inherent errors are so great that the figures in years must be considered merely as indicators of relative age, rather than true figures. They are pegs on which to hang ideas.

If we consider the errors of the several dates, the amount of error varies. Thus, the length of the Post-glacial rests on the incompletely published work of Lidén, but it has been checked as to relative lengths of the intervals by archeological means as far back as the Ancylus and Litorina stages. Also, many pollen analytical studies have been made which reach back into the Gothiglacial substage. These studies confirm the order and general relative length of the substages of the younger Late-glacial and Post-glacial substages. The error in estimation of the length of the Post-glacial substage is probably small and its true length is neither longer nor shorter by more than 10 percent.

As the Fenniglacial period has been measured both in Sweden and in Finland by varve counts, which agree within 100 years, the error in the length of this period is so small that the total error in the elapsed time to the present is no greater than that involved in using the much longer Post-glacial interval.

However, the length of the Gothiglacial is not so well-determined and an estimate of 2,500 years for this time interval is subject to error of as much as 500 years, and in fact, 3,000 years is accepted by many workers. Furthermore, the length of the Daniglacial is uncontrolled by varve counts and is a pure estimate. The date given in Europe for the Pomeranian moraine depends largely on the length of time assigned to the Daniglacial. It is likely that Antevs' date for the St. Johnsbury is more nearly correct. Assuming, therefore, 25,000 years as the elapsed time since the Pomeranian, this estimate may be too large by 25 percent, or too small by as much as 30 percent.

Estimates of the elapsed time to the Brandenburg moraine have no actual basis. In America Antevs' estimate for the "New York" moraine involves a long varve count and therefore, has a value for

the minimum. If 35,000 years is adopted, the figure is 10,000 years longer than the elapsed time to the Pomeranian moraine. The date is, therefore, a minimum; the time figure may be much larger and as great as 60,000 years.

Estimates of the elapsed time to the Iowan is almost purely speculative, but there is every geologic reason for believing that Kay's estimate (1931) of 55,000 years is a minimum, and that the true figure may be twice as large.

These doubts and questions may be put in summary form by listing the time intervals with estimates of the corresponding errors, as in table 4.

TABLE 4.—*Elapsed Time to Important Ice Advances of the Wisconsin, with Estimates of the Percentage Error*

Short designation	American substages	European substages	Years from 1900	Date B. C.	Range in error of estimates:	
					(too small)	(too large)
	Post-glacial (beginning of, at Cochrane)	Post-glacial (beginning of, at Ragunda)	8,700	6,800	*percent* 10	*percent* 10
W4	?	Fennoscandian moraine	10,400	8,500	10	10
		Scanian halt	13,400	11,500	15	10
W3	Mankato	Pomeranian	25,000	23,100	30	25
W2	Tazewell-Cary	Brandenburg	35,000	35,000	75	25
W1	Iowan	Warthe	65,000	65,000	100	10

GLACIAL SUBSTAGES IN COLORADO CORRELATED

In table 5 a correlation is made between the substages of the last glaciation in the Rocky Mountains and those of the continental glaciers of North America and Europe. There is in this correlation a large uncertainty. The only available method of making such a correlation is by a general argument, as it is as yet impossible to use either the vertebrate fossils or the cultural remains as guide fossils. The line of argument is as follows: 1, the pre-Home substage is almost completely obliterated by erosion, a condition, in view of the position of the ice mass in a narrow mountain canyon, more or less comparable to the degree of weathering of the Iowan; 2, the Home moraine retains its topographic form, and the small lateral rock gorge is fresh and shows little weathering, a condition com-

parable to the degree of preservation of the Tazewell-Cary moraines, formerly considered early Wisconsin; 3, the Corral Creek moraine is fresh in form and lacks weathering, much like the Late Mankato moraines of Minnesota. The sequence appears to fit fairly well, although there is no provision for the decided oscillation of the Early Mankato, unless moraines of that age form part of the morainic complex of the Corral Creek substage. 4, The Long Draw substage, by reason of its modest moraines and other evidences of its existence, appears to be recessional, and its correlation with the Cochrane and Fennoscandian moraines seems appropriate. Such an arrangement leaves the Scanian halt without a counterpart.

TABLE 5.—*Correlation and Dating of Rocky Mountain Glacial Stages*

Short desig- nation	North European Continental substages	North American Continental substages	Cache la Poudre Valley, Colorado	Antevs' generalized dating from 1900	Milanko- vitch's generalized dating from 1800
	Post-glacial		Protalus rampart		
W4	Fennoscandian	Cochrane (?)	Long Draw	10,000±	
	Scanian	?	?		
W3	Pomeranian	Late Mankato (St. Johnsbury)	Corral Creek	25,000±	19,500 to 29,500
W2	Weichsel (Brandenburg)	Tazewell-Cary (Harbor Hill)	Home	35,000±	67,000 to 78,000
W1	Warthe (Fläming moraine)	Iowan (Ronkonkoma)	Pre-Home		111,000 to 122,000

This correlation can only be defended by a negative and inconclusive argument that the Home can hardly be other than the climax of the Wisconsin, as understood in North America. If such an assignment is made, the strong readvance of the ice of the Mankato substage, separated from the Tazewell-Cary by an interstadial climate, as shown by the Two Creeks Forest bed (Wilson, 1932), seems to correspond to the similar advance of the Corral Creek moraine. The interval between the Home and Corral Creek substages seems to be too long to fit into any other place in the glacial sequence. The Corral Creek moraine may represent all of the Mankato, but the highest level of its outwash plain is doubtless the equivalent of the Late Mankato. For the present considerations, the glacial substage is traced to the plains by means of the terraces of glacial outwash,

and therefore the late stage of the moraine is the time represented by the terrace.

If this correlation is accepted, the Corral Creek moraine, the Kersey terrace, and the old floor of the Lindenmeier Valley were completed approximately 25,000 years ago. The Long Draw moraine, the Kuner terrace, and the dissection of the Lindenmeier Valley occurred approximately 10,000 years ago. The reader will have no illusions about these dates, and will realize that even if the correlations here made between the valley glaciers of Colorado and the continental ice sheets are entirely correct, the dates themselves are subject to large errors, as previously set forth.

FOLSOM CULTURE OF LATE-GLACIAL AGE

SUMMARY OF EVIDENCE

The difficulties of geochronological work have been reviewed, and the uncertainties set forth. It is now necessary to make application to the antiquity of the Folsom culture.

In brief, the culture layer of the Lindenmeier Valley shows that the Folsom hunters camped on the edge of a springy meadow, when the adjacent minor streams flowed at the level of the 20-foot terrace of these streams. This terrace, traced 30 miles down these minor streams, is correlative with the Kersey terrace of the main rivers of eastern Colorado. Here also, sites at Kersey and at Dent indicate that Folsom hunters camped and hunted on the borders of the river flood plains during this stage. Traced up the Cache la Poudre River, the Kersey terrace is the equivalent of the No. 4 terrace in the mountain canyon. In the narrow rock-walled gorges, the remnants of this terrace are small and infrequent. With reasonable assurance this terrace is interpreted as the valley train of glaciers that extended from the now empty cirques of the high mountains to Chambers Lake and to similar elevations in other canyons. This is the Corral Creek substage of glaciation.

The correlation of this hitherto unrecognized stage of glaciation in the Rocky Mountains with continental glaciation in central and eastern United States involves much uncertainty. It is however thought to be the equivalent of the Late Mankato-St. Johnsbury substage, which in turn is considered the equivalent of the Pomeranian substage in northern Europe. Such a correlation has provided a date in years. Antevs has estimated the St. Johnsbury as separated from our time by 25,000 years, and has argued that the Pomeranian has about the same antiquity. The validity of this date has been

considered in some detail. It is without much question of the right order of magnitude and can be no more than 25 percent too large, or on the other hand more than 30 percent too small.

As the camps and relics of Folsom man are found on the completed surface of the terraces, or in the upper gravel, the culture should be younger rather than older than the climax of this glacial substage. No evidences of Folsom implements have as yet been discovered on the Kuner, the next younger terrace. This terrace and its equivalent, the Long Draw glacial substage are apparently younger than the culture. On a comparable line of reasoning the Long Draw is considered to be the equivalent of the Cochrane and Fennoscandian substages, to which an age of 10,000 years may be assigned.

Thus, the Folsom culture of this area and the Lindenmeier site in particular, have an antiquity which is between 10,000 and 25,000 years, if the errors inherent in the methods used are not too great. These methods have been very thoroughly reviewed. It is obvious that much more confidence can be placed on the statement that the culture is older than 10,000 years, than on the statement that it is as old as 25,000 years. However, it is believed by the writers that the age must be much nearer 25,000 years than 10,000.

EVIDENCE FROM OTHER FOLSOM SITES

Other sites at which Folsom or Folsom-like points have been found in association with extinct animals afford some data on this antiquity. The most important is the locality in the Portales Valley of New Mexico, known as the Clovis site (Howard, 1935). Here, in "bluish" sand, silt, and clay, have been found artifacts and the bones of mammoth and bison. Weathering from these materials, Folsom and Yuma points are found. Diatoms, invertebrate shells, and charcoal from a hearth have been discovered and identified. All point to a climate cooler than the present. In an attempt to fix the date of these deposits, Antevs (1935) has made a number of assumptions: 1, that the "bluish" silts represent lake beds; 2, that these lakes are contemporary with the high stand of Lake Estancia, an ancient lake 160 miles to the west; 3, that Lake Estancia reached its highest stage of water level after the maximum of the Wisconsin glaciation. It should be noted, however, that there is no confirmatory evidence that the moist conditions in the Portales Valley coincided with the high stand of Lake Estancia. This is a plausible but unproved assumption. If it is true, the question then arises whether Antevs' assumption that the Pluvial period, coinciding with the high stand of Lake

Estancia, came after the Wisconsin maximum, or coincided with it, or with one of the later substages of glaciation. As Antevs (1935, p. 310) gives 25,000 years for the culmination of the Wisconsin glaciation, he obviously refers to the Late Mankato-Pomeranian substage, whereas others would place the culmination at the Tazewell-Cary-New York-Brandenburg substage. If the glacial history of the Southern Rocky Mountains herein outlined is followed, and the dates accepted, there were at least four Wisconsin glacial substages: the earliest, or pre-Home, of unknown date, the others 35,000 +, 25,000 ±, and 10,000 ± years ago. The present writers place the climax of the Wisconsin at the time of the Home-Tazewell-Cary-New York-Brandenburg substage, some 35,000 + years ago.

Regardless of the merits of Antevs' meteorological argument that the pluvial periods in the country south of the Rocky Mountains are later than the glacial advances and not coincident with them, it is obvious that there is no direct proof that the lakes are associated with one of these glacial substages rather than with another. The obvious method is to consider the cultural and faunal materials. On such a basis, the Clovis beds may easily be of the same age as the culture layer of the Lindenmeier Valley. The presence of Yuma points, so far not found at the Lindenmeier site, gives a measure of uncertainty to such a correlation.

Folsom points associated with mammoth remains have also been found at Angus, Nebr. (Figgins, 1931), at Miami, Tex. (Sellards, 1938), and 30 miles from Abilene, Tex. (Bryan and C. N. Ray, 1938). None of these localities affords any present help in the problem of a definitive association of the Folsom culture with a datable geologic horizon. At Lake Mojave, in California (E. W. and W. H. Campbell, 1937), Folsom points have been found but not in place. Flint flakes in beach gravel show that man was present when the lake stood high, but his cultural status is uncertain. Rogers (1939, p. 43) states that not only flakes but implements of his Playa culture occur in gravel at this locality, but he casts doubt on the association of the gravel with the lake. The discrimination and tracing of the *Citellus* zone in Nebraska, as described by Schultz and by Lugn (1935, pp. 142-145) affords a promising lead whereby the younger artifact-bearing terraces may be dated. Furthermore, the terraces of the Colorado Piedmont may in the future be traced into the deposits associated with the continental ice in eastern Nebraska. The attribution of the *Citellus* zone to the Peorian, that is, to the interstadial between the pre-Home and Home glaciations, would place the cultures associated with the overlying loess and terrace deposits at a date much too early to fit

into the correlation here made. The continued detailed efforts of the Nebraska geologists promise to provide a solution for this difficult and intricate problem.

GEOGRAPHY OF THE FOLSOM CULTURE

The correlation in time between the Folsom culture and the Corral Creek glacial substage here presented, leads to several conclusions regarding the local and general climatic conditions.

That the climate of the northeastern Colorado Piedmont was cooler is attested by invertebrates found in the Lindenmeier culture layer (Eisley, 1937). It was at times almost Arctic, as shown by the solifluction phenomena still preserved in terrace gravel. Strong winds blew across flood plain surfaces not well protected by vegetation, so that dunes were piled up and pebbles polished and cut by drifting sand. Presumably, the precipitation in the mountain area may have been greater. In the plains, however, a dry, near-Arctic climate must be postulated, similar to that of the Canadian Great Plains. The cold drying winds from the mountains prevented the formation of true forests, so that presumably the plains were covered by prairie types of vegetation, with only scattered groves of trees.

In such a severe environment the sheltered Lindenmeier Valley, with grass and water in its springy meadow, must have been an ideal spot—a place beloved by the beasts. Here a hunting people would find year after year the necessities—water and game for food. It is, however, hard to believe that the larger grazing animals remained in the area in the winter. Just as the bison of recent history migrated southward to more genial winter climates, so the ancient bison probably also migrated. Doubtless, the hunters moved with the animals. If so, an explanation for the lack of remains of shelters at the Lindenmeier site is afforded, and an explanation is presented for the wide distribution of Folsom finds throughout the Great Plains region, from Saskatchewan to Texas.

BIBLIOGRAPHY

ALDEN, W. C.
    1932. Physiography and glacial geology of eastern Montana and adjacent
        areas. U. S. Geol. Surv., Prof. Pap. 174.
ANTEVS, ERNST
    1922. The recession of the last ice sheet in New England. Amer. Geogr.
        Soc. Res. Ser., No. 11.
    1928. The last glaciation, with special reference to the ice retreat in north-
        eastern North America. Amer. Geogr. Soc. Res. Ser., No. 17.
    1931. Late-glacial correlations and ice recession in Manitoba. Geol. Surv.
        Canada, Mem. 168.

1935. Age of the Clovis lake clays. Proc. Acad. Nat. Sci., Philadelphia, vol. 87, pp. 304-312.

1936. Correlation of late Quaternary chronologies. Int. Geol. Congr., Rep. 16th Sess., U. S. A., vol. 1, pp. 213-216.

ATWOOD, W. W., JR.

1937. Records of Pleistocene glaciers in the Medicine Bow and Park Ranges. Journ. Geol., vol. 45, pp. 113-140.

ATWOOD, W. W., and MATHER, K. F.

1932. Physiography and Quaternary geology of the San Juan Mountains, Colorado. U. S. Geol. Surv., Prof. Pap. 166.

AUGHEY, SAMUEL

1876. U. S. geological and geographical survey of Colorado and adjacent territories (Hayden Survey). Ann. Rep. Progress for 1874, pp. 241-266.

BLACKWELDER, ELIOT

1929. Sandblast action in relation to the glaciers of the Sierra Nevada. Journ. Geol., vol. 37, pp. 256-260.

1931. Pleistocene glaciation in the Sierra Nevada and Basin Ranges. Bull. Geol. Soc. Amer., vol. 42, pp. 865-922.

BROWN, BARNUM

1929. Folsom culture and its age (abstr.). Bull. Geol. Soc. Amer., vol. 40, pp. 128-129.

BRYAN, KIRK

1926. Recent deposits of Chaco Canyon, New Mexico, in relation to the life of the prehistoric peoples of Pueblo Bonito (abstr.). Journ. Washington Acad. Sci., vol. 16, pp. 75-76.

1929. Folsom culture and its age (Barnum Brown abstract with discussion by Bryan). Bull. Geol. Soc. Amer., vol. 40, pp. 128-129.

1934. Geomorphic processes at high altitudes. Geogr. Rev., vol. 24, pp. 655-656.

1936. Geologic features in New England ground water supply. New England Waterworks Assoc. Journ., vol. 50, pp. 222-228; and Harvard Alumni Bull., vol. 39, pp. 676-681.

1937. Geology of the Folsom deposits in New Mexico and Colorado. Early man, a symposium, pp. 139-152. G. G. MacCurdy, ed. Lippincott Co., Philadelphia.

1938. Prehistoric quarries and implements of pre-Amerindian aspect in New Mexico. Science, n. s., vol. 87, pp. 343-346.

BRYAN, KIRK, and RAY, CYRUS N.

1938. Long channelled point found in alluvium beside bones of *Elephas columbi*. Bull. Texas Arch. and Paleont. Soc., vol. 10, pp. 263-268. (Also printed as: Folsomoid point found in alluvium beside a mammoth's bones. Science, n. s., vol. 88, pp. 257-258.)

CAMPBELL, E. W. and W. H.

1937. The archeology of Pleistocene Lake Mohave. Southwest Mus. Pap., No. 11, 118 pp.

COOK, H. J.

1927. New geological and paleontological evidence bearing on the antiquity of mankind in America. Nat. Hist., Amer. Mus. Nat. Hist., vol. 27, pp. 240-247.

DALY, R. A.
  1934. The changing world of the ice age. Yale Univ. Press.
DE GEER, GERARD
  1926. On the solar curve, as dating the ice age, the New York moraine, and
        Niagara Falls through the Swedish time-scale. Geogr. Annaler,
        vol. 8, pp. 253-283.
EISLEY, L. C.
  1937. Index Mollusca and their bearing on certain problems of pre-history;
        a critique. Philadelphia Anthrop. Soc., Twenty-fifth Anniversary
        Studies, pp. 77-93. Univ. Pennsylvania.
FIGGINS, J. D.
  1927. The antiquity of man in America. Nat. Hist., Amer. Mus. Nat. Hist.,
        vol. 27, pp. 229-239.
  1931. An additional discovery of the association of a "Folsom" artifact and
        fossil mammal remains. Proc. Colorado Mus. Nat. Hist., vol. 10,
        No. 4.
  1933. A further contribution to the antiquity of man in America. Proc.
        Colorado Mus. Nat. Hist., vol. 12, No. 2.
FLINT, R. F.
  1935. How many glacial stages are recorded in New England? Journ.
        Geol., vol. 43, pp. 771-777.
FULLER, M. L.
  1914. The geology of Long Island, New York. U. S. Geol. Surv., Prof.
        Pap. 82.
GAMS, HELMUT
  1938. Die bisherigen Ergebnisse der Mikrostratographie für die Gliederung
        der letzen Eiszeit und des Jungpaläolithikums in Mittel- und
        Noreuropa. Quartär, vol. 1, pp. 75-96.
HOBBS, W. H.
  1931. Loess, pebble bands, and boulders from glacial outwash of the
        Greenland continental glacier. Journ. Geol., vol. 39, pp. 381-385.
HOWARD, E. B.
  1935. Evidence of early man in North America. Mus. Journ., Univ. Penn-
        sylvania, vol. 24, Nos. 2-3, pp. 61-158.
JOHNSON, W. D.
  1901. The High Plains and their utilization. U. S. Geol. Surv., 21st Ann.
        Rep., pt. 4, pp. 599-741.
JOHNSTON, W. A.
  1928. The age of the Upper Great Gorge of Niagara River. Roy. Soc.
        Canada, Proc. and Trans., 3d ser., vol. 22, sec. 4, pp. 13-29.
KAY, G. F.
  1931. Classification and duration of the Pleistocene period. Bull. Geol. Soc.
        Amer., vol. 42, pp. 425-466.
LEIGHTON, M. M.
  1926. A notable type Pleistocene section; the Farm Creek exposure near
        Peoria, Illinois. Journ. Geol., vol. 34, pp. 167-174.
  1931. The Peorian loess and the classification of the glacial drift sheets of
        the Mississippi Valley. Journ. Geol., vol. 39, pp. 45-53.
LEVERETT, FRANK
  1939. The place of the Iowan drift. Journ. Geol., vol. 47, pp. 398-407.

LIDÉN, RAGNAR
   1913. Geokronologiska studier öfver det finiglaciala skedet i Angermanland.
       Afhandl. Sveriges Geol. Undersökn., ser. C., No. 9.
LUGN, A. L.
   1935. The Pleistocene geology of Nebraska. Nebraska Geol. Surv., 2d ser.,
       Bull. 10.
   1938. The Nebraska State Geological Survey and the "Valentine Problem."
       Amer. Journ. Sci., vol. 36, pp. 220-227.
MACCLINTOCK, PAUL, and RICHARDS, H. G.
   1936. Correlation of late Pleistocene marine and glacial deposits of New
       Jersey and New York. Bull. Geol. Soc. Amer., vol. 47, pp. 289-338.
MARTIN, R. J.
   1930. Climatic summaries of the United States. Section 23, northeastern
       Colorado. U. S. Weather Bur.
MILANKOVITCH, M.
   1930. Mathematische Klimalehre und astronomische Theorie. der Klima-
       schwankungen. Handb. Klimatol., 1, A, Berlin.
RAY, CYRUS N.
   1938. The Clear Fork culture complex. Bull. Texas Arch. and Paleont.
       Soc., vol. 10, pp. 193-207.
RAY, LOUIS L.
   1935. Some minor features of valley glaciers and valley glaciation. Journ.
       Geol., vol. 43, pp. 297-322.
   1938. Recent physiographic development along the northern Front Range
       (abstr.). Proc. Geol. Soc. Amer. 1937, p. 314.
RICHTER, KONRAD
   1937. Die Eiszeit in Norddeutschland. Gebrüder·Borntraeger, Berlin.
ROBERTS, F. H. H., JR.
   1935. A Folsom complex, preliminary report on investigations at the
       Lindenmeier site in northern Colorado. Smithsonian Misc. Coll.,
       vol. 94, No. 4.
   1936. Additional information on the Folsom complex, report on the second
       season's investigations at the Lindenmeier site in northern Colorado.
       Smithsonian Misc. Coll., vol. 95, No. 10.
   1937. The Folsom problem in American archeology. Early man, a sym-
       posium, pp. 153-162. G. G. MacCurdy, ed. Lippincott Co., Phila-
       delphia.
ROGERS, MALCOLM J.
   1939. Early lithic industries of the lower basin of the Colorado River and
       adjacent areas. San Diego Mus. Pap., No. 3, 75 pp.
ROMER, A. S.
   1929. A fresh skull of an extinct American camel. Journ. Geol., vol. 37,
       pp. 261-267.
   1933. Pleistocene vertebrates and their bearing on the problem of human
       antiquity in North America. American Aborigines, publ. for pres.
       at 5th Pacific Sci. Congr., Canada, pp. 47-85. Univ. Toronto Press.
SAURAMO, MATTI
   1928. The Quaternary geology of Finland. Bull. Comm. Geol. Finlande,
       No. 86, pp. 1-110.

SCHULTZ, C. B.
    1932. Association of artifacts and extinct mammals in Nebraska. Nebraska
        State Mus., Bull. 33, vol. 1, pp. 271-282.
SELLARDS, E. H.
    1938. Artifacts associated with fossil elephant. Bull. Geol. Soc. Amer.,
        vol. 49, pp. 999-1010.
SOERGEL, WOLFGANG
    1925. Die Gliederung und absolute Zeitrechnung des Eiszeitalters. Fortschr.
        Geol. und Pal., vol. 13, 251 pp.
    1937. Die Vereisungskurve. Gebrüder Borntraeger, Berlin.
TAYLOR, F. B.
    1913. Niagara Falls and Gorge. 12th Int. Geol. Congr., Canada, Guide Book
        No. 4, pp. 5-70.
VAN TUYL, F. M., and LOVERING, T. S.
    1935. Physiographic development of the Front Range. Bull. Geol. Soc.
        Amer., vol. 46, pp. 1291-1350.
WAHLSTROM, E. E.
    1939. Geology of west central Boulder Co., Colorado. Unpublished doc-
        torate thesis, Harvard Univ.
WENTWORTH, C. K.
    1936. An analysis of the shapes of glacial cobbles. Journ. Sed. Petrol.,
        vol. 6, pp. 85-96.
WILSON, L. R.
    1932. The Two Creeks Forest bed, Manitowoc Co., Wisconsin. Trans.
        Wisconsin Acad. Sci., vol. 27, pp. 31-46.
WOODWORTH, J. B., and WIGGLESWORTH, EDWARD
    1934. Geography and geology of the region including Cape Cod, the Eliza-
        beth Islands, Nantucket, Marthas Vineyard, No Mans Land, and
        Block Island. Mem. Mus. Comp. Zoöl. Harvard Coll., vol. 52.
ZEUNER, F. E.
    1935. The Pleistocene chronology of central Europe. Geol. Mag., vol. 72,
        pp. 350-376.

1. Spring at the Lindenmeier site. The water seeps out along the top of the tuff-clay several feet above the top of the storage tank. The tents of the Smithsonian Institution Expedition are on the level of the old valley floor.

2. Brennigan Spring. The light-colored ground is covered with the ordinary grama grass of the dry hills and plains. The dark areas extending down the sides of the gulch are meadow grasses supported by the emerging ground water,

1. The Kersey terrace. View to the north, across the terrace to the South Platte River. Folsom artifacts have been found in the dune sand in the foreground, which rests on the Kersey terrace.

2. View to the east from the summit of Prairie Divide. Plains of the Colorado Piedmont in background. Valley in foreground filled with irregular masses of slumped gravel and glacial debris.

The Home moraine, as seen from the upstream side. The Cache la Poudre River flows from right to left in front of the moraine, and through the channel between the moraine and the left valley wall.

1. View across the valley of the Cache la Poudre River at Home Post Office. Home moraine shows as grassy slope in lower left. Glacial erratics of pre-Home glacial substage shown at A and B.

2. The Corral Creek moraine as seen from upstream side. Note subdued aspect and lack of boulders on the surface of this relatively young moraine. Corral Creek flows through a notch in moraine on right.

1. Pitted outwash plain of the Long Draw substage. Corral Creek cirque in the background (see near view below).

2. Protalus rampart of the Corral Creek cirque. Small patches of snow have remained throughout the summer in sheltered niches in the headwall of this cirque (September 1936).

RITUAL ABLATION OF FRONT TEETH IN SIBERIA AND AMERICA

(WITH FIVE PLATES)

BY
ALEŠ HRDLIČKA
Curator, Division of Physical Anthropology
U. S. National Museum

RITUAL ABLATION OF FRONT TEETH IN SIBERIA AND AMERICA

(WITH FIVE PLATES)

BY

ALEŠ HRDLIČKA

Curator, Division of Physical Anthropology
U. S. National Museum

(PUBLICATION 3583)

RITUAL ABLATION OF FRONT TEETH IN SIBERIA AND AMERICA

By ALEŠ HRDLIČKA

Curator, Division of Physical Anthropology
U. S. National Museum

(WITH FIVE PLATES)

INTRODUCTION

My attention to the subject of early noncurative removal of teeth in America was called more directly in 1914 by a request from Dr. J. W. Jackson, of England, for information as to such practice on this continent. Not long after, Dr. Jackson [1] published an interesting paper on such a procedure in the neolithic times of Britain, in which he quoted my reply to him, as follows (p. 78) :

> Dr. A. Hrdlička informs me that the only dental mutilation of which he has a direct and positive knowledge is the filing of the front teeth among the prehistoric Tarasco, and some other tribes in Central and Southern Mexico. He states further that he has often seen in prehistoric skulls from Mexico and other localities a complete loss of the median upper incisors, and it is quite possible that in some of these cases at least the teeth were removed ceremonially; but he has no absolute proof of such a practice, and has never met with it among the living Indians. Personally, he is inclined to believe that the practice has existed in some parts of America.

During our excavations in Alaska, 1926-38, we have repeatedly come across crania and lower jaws which showed plainly that some or even all their incisors, and in a few instances even a canine, had been removed in life, and everything indicated that the removal had been that of healthy teeth, that it took place in youth, and that it was not accidental. As specimens of this nature accumulated, it became evident that we were confronted here with a definite custom, which in all probability was a part of the initiation rites of the youth, parallel to that in aboriginal Australia and other parts of the world, and which conferred on the sufferers a certain distinction.

As the Alaskan materials accumulated, it was seen that the practice varied in frequency, and also in intensity, in different parts of the

---

[1] Jackson, J. W., Dental mutilations in neolithic human remains. Journ. Anat. and Physiol., vol. 49, pp. 72-79, 1914-15.

region; that it affected both sexes; that it was carried out, probably with the help of a sinew, by forcibly pulling the upper teeth forward, or downward and forward, and lower teeth forward, or upward and forward; that it resulted in general in the breaking of the anterior wall of the alveolus, rarely even in the breaking of the crown from the root and a retention of the latter; and that as a rule, with rare exceptions, it was followed by a normal healing, with subsequent gradual absorption of the affected alveolar portion.

I have since noted many an example of such a loss of teeth, but there was not sufficient incentive to make a special study of the matter until my recent trip to the U.S.S.R., when I found that the practice was once widespread also over Siberia.

During the examination, in the summer of 1939, of large parts of the Siberian craniological collections in Leningrad, Moscow, and Irkutsk, I came repeatedly across such tooth ablation in materials from the neolithic to recent periods. The kind and number of removed teeth, the nature, as far as discernible, of the operation, and the after effects all were practically the same as those in Alaska. But the practice in Siberia evidently reached farther back in time.

On my return I reexamined parts of our collections and came across so much of interest that I undertook a closer survey of the conditions connected with this practice.

A search through literature soon made it evident that thus far the presence of the practice of ritual and other noncurative tooth ablation on this continent has failed to be definitely reported. I addressed six of the foremost American workers in anthropology and ethnology for information as to any publications on, or knowledge of, ritual or related teeth removal in America, and the answers were all negative. A search through the writings on the subject elsewhere was almost equally disappointing as far as both the American continent and Siberia were concerned; but it produced two or three valuable old references to such practices in ancient Darien and Peru and showed that such ablations, together with tooth filing, had been met with repeatedly by Japanese scholars in the skulls of the neolithic Ainu.

A direct examination of our collections soon showed how easy it is to pass over such details when special attention is not directed to them. Some of the material had been studied for conditions of the teeth by dentists and anthropologists without the true facts having been discerned. I myself have missed them in some of the older series. Even with experience, however, and direct focusing on the

subject, the true or full diagnosis of the cases falling into this category is not easy.

MUTILATION OF TEETH

There are but a few parts of the human body that somewhere, at some time, have not been subjected to mutilation. The head and even the neck (Burma) were deformed; ears, nose, and lower lip pierced for introduction of decorative objects, lower lip stretched, beard elapidated, face and body tatooed or scarred, breasts compressed, genitals cut, legs and feet deformed, and fingers cut off. The motives for, and the objects of, these practices were multiple. They were simple decoration; forms of class, tribal, ritual, or individual branding; testimony of distinction or of endurance; sacrificial offering; grief manifestation; or simply a fashion, and rarely a punishment for transgression.

Among the parts and organs affected by such practices the teeth received a large share of attention. They were stained black or red, filed in many different patterns, inlaid with gold or precious stones, or wholly removed by knocking out or extraction. These practices were limited to the teeth that showed most—the incisors, the canines, and even the anterior premolars. They differed from tribe to tribe, locality to locality, and even in smaller groups. A single tooth in some cases was knocked out to brand a slave. In rare instances (Africa, Japan), the lower incisors were removed and the upper serrated by filing, possibly from cosmetic or other motives; most often, however, the teeth were removed, in a few places seemingly only in the females or males but mostly in both sexes, as a part of the ritual of initiation of the boy or girl into manhood or womanhood.

Such practice of a ceremonial ablation of two or more of the front teeth was widely spread over the world and dated from remote antiquity. It originated apparently during upper paleolithic times, extended irregularly over a large part of the Old and even the New World during the neolithic period, and remained to be practiced among various peoples down to recent and even to the present time.

Since the latter part of the last century the whole subject of dental mutilation outside of America (and Siberia) has received considerable scientific attention, particularly by the Germans, the French, and the Japanese, and there are a number of comprehensive contributions to it in literature. The most notable of these are those of Von Ihering,[2]

---

[2] Von Ihering, H., Die künstliche Deformierung der Zähne. Zeitschr. Ethnol., vol. 13, pp. 213-262, 1882.

Hamy,[3] Lasch,[4] Ankerman,[5] Van Rippen,[6] Lignitz,[7] Koganei,[8] Wittek,[9] and Hasebe,[10] all of whom give references to further literature. Except for the Japanese, however, the authors named devote most of their attention to teeth filing, inlays, and other decorations.

ANTIQUITY

No trace of ritual removal of teeth has as yet been noted in the middle or older paleolithic. According to present evidence, the practice originated in postglacial, upper paleolithic times, after man had reached the modern type, had multiplied considerably and spread far over the Old World, and had had time to develop some forms of society and religion.

The oldest instances of what is evidently ritual tooth ablation were reported in 1895 by Newton[11] in the Galley Hill skull; in 1932-33 by Boule and Vallois in the Asselas and Afalou upper paleolithic crania from southern Sahara; and by Keith in Miss Garrod's mesolithic or Caspian skulls from Shukba, Palestine. In neolithic times the practice

---

[3] Hamy, E. T., Les mutilations dentaires aux Mexique et dans le Yucatan. Bull. Soc. Anthrop. Paris, vol. 5, pp. 879-887, 1882.

[4] Lasch, R., Die verstümmlung der Zähne in Amerika und Bemerkungen zur Zahnedeformierung im Allegemeinen. Mitt. Anthrop. Ges. Wien, vol. 31, pp. 13-22, 1901.

[5] Ankerman, B., Kulturkreise und kulturschichten in Afrika. Zeitschr. Ethnol., vol. 37, p. 65, 1905.

[6] Van Rippen, Bene, Mutilations and decorations of teeth among the Indians of North, Central and South America. Journ. Allied Dental Soc., vol. 13, pp. 219-242, 1918.

[7] Lignitz, H., Die künstlichen Zahnverstümmlungen in Afrika im Lichte der Kulturkreisforschung. Anthropos, vols. 14-15, pp. 891-943, 1919-20; vols. 16-17, pp. 247-264, 866-889, 1921-22.

[8] Koganei, Y., Über die künstliche deformation des Gebisses bei den Steinzeitmenschen Japans. Mitt. Med. Fak. Univ. Tokyo, vol. 28, pp. 429-485, 1922.

[9] Wittek, M., Die künstlichen deformierungen der Zähne bei den wilden Völkern. Inaug.-Diss., Breslau, 70 pp. 1924.

[10] Hasebe, K., Über die Zahnverstümmelungsformen bei den Steinzeitmenschen Japans. Arb. Anat. Inst. Sendai, vol. 11, pp. 61-106, 1925.

[11] Newton, E. T., Quart. Journ. Geol. Soc., vol. 51, p. 508, 1895, quoted in Jackson, J. W., Journ. Anat. and Physiol., vol. 49, p. 72, 1915: "The only evidence of missing teeth in British fossil human remains appears to be that of the famous and much disputed Galley Hill skeleton described by Mr. E. T. Newton in 1895. In his description of the lower jaw the author remarks: 'On each side of the symphysis the alveolar border is broken; but while portions of the alveoli for the two outer incisors are preserved, there are no traces of the alveoli for the two median incisors, which must have been either very short or else lost during life, and the alveoli filled up by bone.'"

was apparently already widely spread over Africa, Australia, continental Asia, and Japan, and had even reached some spots in Europe.[12] In our time it still survives in Africa, Australia, probably Mongolia, and possibly parts of South America.

RECOGNITION

As the effects on the jaws of the removal of healthy teeth differ but little, if any, from those following a loss of teeth from accident or other causes, the question naturally poses itself, how can the observer safely diagnose his cases? Such a diagnosis, with sufficient experience, is fortunately not overdifficult. The criteria of ritual or related loss of teeth are lack of evidence of disease; symmetry or near symmetry of the removals; repetition of similar losses in the same group; the breaking of the labial wall of the alveolus; signs that the removal has taken place in youth; existence of the practice among neighboring or related peoples; and sometimes legendary or other relevant information. Primitive people, especially in youth, have suffered but little, or not at all, from caries; an accident would only very exceptionally produce a symmetrical loss of teeth, and such a loss would not be likely to be repeated in others of the same group and especially in both sexes. The picture of the jaws after ritual or other intentional ablations of sound teeth, once learned, is too characteristic to be forgotten or to lead to serious errors. A real difficulty is encountered only in groups where caries was more common, and in the aged who have lost many teeth from various reasons.

In the writer's reports here only those cases were included where no reasonable doubt as to the nature of the tooth loss existed. However, the matter deserves some further consideration.

---

[12] Jackson (ibid.) reports the following cases from the neolithic of England: *"Neolithic cave on Warton Crag, Lancashire.* The history of the Warton finds is as follows: In 1909, whilst excavating in the Dog Holes cave, I discovered a number of human remains, amongst them being a lower jaw which was remarkable for the absence of the second premolar teeth on either side, and with all traces of the alveoli obliterated. I also met with an upper jaw from which the two median incisors had been extracted some time before death.

"In 1912, whilst conducting further excavations at the same cave, I had the good fortune to discover another human lower jaw exhibiting exactly the same remarkable dental mutilations as in that found in 1909." (Pp. 72, 73.)

". . . In searching through the large number of human remains from the Perthi Chwareu caves (now in the Manchester Museum), I discovered another example of an upper jaw where the two median incisors have been removed, but in this case both alveoli are completely grown up with bone." (Pp. 75-76.)

Ritual and other intentional noncurative forms of tooth extraction, found in skeletal materials, must be differentiated from:

1, Congenital absence of teeth;
2, loss by accident;
3, extraction for caries;
4, loss by disease;
5, loss in old age.

1. A congenital absence of any of the frontal dental elements, aside from impactions and outside of the white race, is very rare and perhaps limited to the lateral incisors. It is doubtful if in the American Indian there is ever a congenital absence of one or both of the median incisors, canines or premolars. In the few instances of Indian skulls with an apparently congenitally missing anterior tooth that have come under my observation, the absent unit was without exception a single upper lateral incisor, and in view of later experience I could in none of these cases remain certain that the absence was truly congenital. In a congenital case there would be no alveolus and probably not even a space for it, with the neighboring teeth in apposition. There are a few instances where there is a space large enough for a tooth between two other teeth, with the alveolar border well represented and showing no sign of a previous alveolus or of any injury. Should such cases occur in a group where no ablation was practiced, the diagnosis would be easier; but where one is found in a series in which other specimens show clearly intentional removals, the possibility that they may be merely exceptionally well-healed cases after an early extraction cannot be excluded. It is indeed quite evident now that any reports on "congenitally absent" teeth in the Indian, hitherto made, need revision. But even if such cases as those mentioned above were congenital, there are so very few of them that they could not seriously interfere with the study of the conditions under consideration.

2. Teeth lost by accident, unless this also affected the alveolar process, would leave the same lesions as those forced out by design. But accidents are much more variable than a definite practice, both as to time and kind, and would present less symmetry and less repetition. The American skulls from tribes where, or times when, no ablation was practiced are as a rule free also from accidental losses, though there may possibly be a group or groups where, owing to some peculiar habits, accidental knocking out of teeth may have occurred. Such incidents, I am told, take place occasionally during the game of lacrosse among the present Iroquois, but the Iroquois skulls in our possession show no such injuries, nor have they been reported from the many other lacrosse-playing groups. Moreover, there were groups—and, of

course, women in general—who did not play lacrosse, yet show a variety of ablations.

3. Caries, especially in the canines and median incisors, was either completely absent, as in the Eskimo or other Alaskan as well as the older Siberian groups, or developed infrequently and later in life ; and, when the disease occurred, extractions—as seen from skulls and as has been learned among the living—were practiced but very seldom. The criteria for distinguishing a noncurative ablation from that for caries are the absence or rarity of caries in the group ; the absence of the disease from the denture of the individual under examination, or its absence at least from the teeth adjoining the lesion ; indications that the ablation of the front teeth took place early in life ; and the symmetry or resemblance of the removals and their repetition in the group.

4. The diseases other than caries which occasionally caused the loss of teeth among the American natives, were abscesses about the roots, pyorrhea, and scurvy. Apical abscesses were fairly common in the elderly and old, absent to rare in the younger. The tooth often remained until it must almost have dropped out, and there was left in and above the alveolar process a characteristic smooth hollow which would always be easy of recognition. Moreover such abscesses in general followed advanced abrasion of the teeth with exposure of the pulp, which of course did not take place in youth. Pyorrhea, absent in the Eskimo, was limited among the Indians to some of the elderly, especially among the sedentary tribes. Just how many teeth were lost through it, it is impossible to say, but such losses would be irregular. Scurvy, too, was not a disease of the young, and it affected all or nearly all the teeth, resulting, when not fatal, in a characteristic picture of the jaws. With adequate experience and ordinary care, there is no great danger of confounding the noncurative ablations with loss of teeth from any of these pathological conditions.

5. Old age, at least in the sedentary American groups, often played havoc with the teeth and with the alveolar processes. The agencies were extreme abrasion, abscesses, pyorrhea, and extrusion of the teeth with retraction of the alveolar processes. In most of the skulls of the very old the change in the jaws had reached such a degree that the distinguishing of any early ablations becomes difficult or quite impossible. Such specimens are best left out of consideration. Almost equally difficult are cases in which, from some cause other than very old age, there has been a loss of more or less of the back teeth including one or both the premolars, on one or both sides. Unless such a loss of

the premolars was fairly recent or occurs in a skull in which there was no ablation of any of the other front teeth, its correct diagnosis is impossible.

As to *removals of teeth for punishment,* this would in all probability be limited to a few individuals or to a restricted locality, would show only one type, and would be found only in adult or elderly males. It may, however, have been more extensively practiced. But a clear recognition of such cases in skeletal collections, without some additional information, would be impossible.

A simple *branding,* as that of slaves, could only be recognized with the aid of sufficient circumstantial evidence. This would include a different kind of burial, perhaps a different skull type, knowledge of such practice in the region, and uniform limited removal of teeth.

Ablation in young children, considerably before puberty, could only be surmised if the changes in the alveolar process were extreme and the approachment of the neighboring teeth considerable; but the question would call for corroboration by the skulls of children from the same locality.

A removal of one or more of the front teeth *on the death of a beloved husband or child,* while not reported, cannot be said to have been impossible; but such cases would likely be limited to women. They could not be distinguished in skeletal material.

EFFECTS ON JAWS

The effects of the early removal of from one to all of the front teeth varied with the number of teeth that had been removed and with the length of time that had elapsed since the removal. In both respects such effects paralleled closely those of modern extractions. There was but one difference—the labial wall of the affected alveolus was, in most of the cases here dealt with, broken through as a result of the crudeness of the operation. Subsequently, as a rule there was normal healing, followed slowly by a closure of the empty alveoli and a gradual absorption of those parts of the alveolar process that had sustained the now missing teeth. In some of the minor cases there took place considerable approach of the remaining teeth, though they never came to a full apposition; in other cases the neighboring teeth and parts were but little affected. The elapsed time since the extraction was naturally a factor in these changes. When teeth were removed from one jaw only, the opposing teeth extruded more or less, without being lost.

The frontal void in the dental arch, especially where more than one tooth was removed, must have caused difficulties in mastication, and especially in speech, but this evidently was no deterrent to the custom.

CONNECTION WITH ARTIFICIAL SHAPING OF TEETH

In many tribes in Africa the custom of knocking out some of the front teeth is found associated with artificial pointing or otherwise shaping of the teeth, and some authors (e.g., Lignitz) have expressed the opinion that the two practices may be closely related. It is possible that such a relation has developed in some of the African tribes, particularly those where the proximal edges of the upper median incisors are removed to form a pronounced notch between the teeth, which resembles the notch left after a removal of these teeth. In general, however, there is much to indicate that the two practices are quite separate. There are tribes in Africa in which either the shaping of the front teeth, or the knocking out of these teeth, exists alone. In Australia knocking out of the teeth is widely spread, but there is no shaping. The same is true of the upper paleolithic and neolithic crania from Africa and other parts of the Old World, in which one or more of the incisors have been removed in youth; and there is no shaping of the teeth in any of the Siberian or American series thus far found in which ritual tooth ablation had been practiced. Koganei,[13] however, has reported one such case in a neolithic Aino. In this case the upper incisors were all notched, and the lower ones had all been removed. On the other hand, tooth filing was in vogue among the pre-Columbian Tarasco, in Mexico, but as far as known there was no ablation.

It is further doubtful whether pointing and other shaping of the front teeth was practiced at the same age as the removal of teeth, and if it had the same significance. Ethnologically, of course, both practices belong to the large class of purposive mutilations of the human body; but whereas the loss of the front teeth was a mark of distinction, the shaping of teeth had rather an esthetic and otherwise psychological value.

---

[13] Koganei, R., On the custom of modifying the natural form of the teeth practiced among the stone-age people of Japan. Journ. Anthrop. Soc. Tokyo, vol. 34, pp. 349-367, 1919. (In Japanese.)

INTENTIONAL NONCURATIVE REMOVAL OF TEETH
IN AMERICA AND SIBERIA

References to such removals in American literature are very scanty, and actual data are as yet nonexistent aside from three or four brief notices; as already mentioned, none have as yet been found in connection with Siberia.

The first known allusions to the practice of knocking out teeth in America occur in Gomara,[14] Pedro de Cieza,[15] and Garcilasso.[16] They extend to some of the tribes of Darien, Panama; the Guanavilcas of Ecuador; the old Peruvians. In Darien, Bancroft,[17] from early Spanish sources—possibly Oviedo, but also Gomara—reports that among the tribes of that region "the prisoner is the slave of the captor; he is branded on his face and one of his front teeth is knocked out." As to the Guanavilcas, Pedro de Cieza[18] says that among these Indians the fathers used to knock out three upper and three lower teeth of their youngsters, believing that thereby they were offering a grateful sacrifice to their deity.

According to Garcilasso[19]—quoted by Lasch[20]—the Inca Huyna Capac punished a rebellious chief by having his teeth taken out, and this was to be applied also to his descendants. Martius[21] said that apparently punishment by removal of teeth was not rare among the old Peruvians.

Joyce,[22] after Cieza de Leon, gives the following account of a punishment by the Inca of insubordinate natives on the island of Puna and of the neighboring district of Huancavillca:

The Inca extracted a terrible vengeance; large numbers of the islanders and Huancavillca were put to death in a cruel fashion, and the survivors on the mainland were compelled, as a mark of disgrace, to extract four teeth in addition to the two which each individual removed in accordance with local custom. The imposed ordinance was still observed at the time of the Spanish conquest.

---

[14] Historia general de las Indias, vol. 1, chap. 68, 1552. (1932 ed., Madrid.)
[15] Istoria del Peru, pp. 99, 106b, Venezia, 1556.
[16] Commentarios Reales, pt. 1, lib. 9, chap. 3, 1609.
[17] Bancroft, H. H., The native races of the Pacific States, vol. 1, p. 764. New York, 1874. (Does not give exact source of statement.)
[18] Op. cit.
[19] Op. cit.
[20] Op. cit.
[21] Beiträge zur Ethnographie und Sprachenkunde, zumal Brasiliens, Amerika's, vol. 1, p. 72.
[22] Joyce, Th. A., South American Anthropology, p. 58. London, 1912.

Schmidt [23] says:

In South America the knocking out of teeth is of the rarest occurrence; I find but three attested cases: among the Paresi, one of the Arawak tribes (the upper incisors); [24] on the West Coast of Ecuador among the Huankavilka (two or three of the upper and lower incisors); and among the Guayakil.[25]

Quoting from a manuscript by A. A. de Motta, Von den Steinen [26] reports that among the central-Brazilian tribe of Kabischi, "in general in both the men and the women the upper incisors are missing."

To these may be added the following: Davis [27] reports a female skull from Pisac, near Cuzco, in which "the front teeth have been punched out in early life" (p. 242); and a female Aymara skull, from Africa, in which "all the upper and one of the lower incisors have been knocked out in early life" (p. 244). Virchow [28] observed, once in a male skull of Santa Catalina and once in a female skull of Santa Barbara, a loss of the right upper median incisor with an obliteration of the alveoli that indicated an early loss. He also observed an ablation of both the lower median incisors in a female skull of Santa Catalina.[29]

NEW DATA

The above scanty records on purposeful ablation of sound teeth in America can now be supplemented by new evidence of importance. There are now in the Division of Physical Anthropology of the United

---

[23] Schmidt, P., Kulturkreise und Kulturschichten in Südamerika. Zeitschr. Ethnol., vol. 45, p. 1038, 1913: "Das Zahnausschlagen ist überhaupt in Südamerika aüsserst selten; ich finde nur drei Fälle bezeugt: bei den Paresi, einem Arowak-Stamm (obere Schneidezähne), dann an der Westküste von Ecuador bei den Huankavilka (zwei oder drei Schneidezähne oben und unten), und bei den Guayakil."

[24] Von den Steinen, Karl, Unter den Naturvölkern zentral-Brasiliens, p. 427. Berlin, 1894.

[25] Verneau, R., and Rivet, P., Ethnographie ancienne de l'Equateur. Mission du Service Géographique de l'Armée pour la mesure d'un arc de méridien équatorial en Amérique du Sud 1899-1906, tom. 6, fasc. 1, p. 53, Paris, 1912; also Saville, M. H., The antiquities of Manabi, Ecuador. Contr. South Amer. Arch., vol. 1, 1907; vol. 2, p. 8, 1910.

[26] Op. cit. "Allgemein fehlen Männern und Frauen die oberen Schneidezähne."

[27] Davis, J. Barnard, Thesarus Craniorum. London, 1867.

[28] Virchow, Rudolf, Beiträge zue Craniologie der Insulaner von der Westküste Nordamerikas. Zeitschr. Ethnol., vol. 21, p. 395, 1889.

[29] "Zweimal ist der rechte obere mittlere Schneidezahn ausgeschlagen und die Obliteration der Olveole deutet auf eine sehr frühe Entstehung: S. Catalina Nr. 9 (♂) und S. Barbara Nr. 6 (♀). Möglicherweise ist die Entgernung absichtlich geschehen. Noch auffallender ist der Verlust der beiden unteren mittleren Schneidezähne bei dem weiblichen Schädel von S. Catalina Nr. 18."

States National Museum several large cranial collections that make feasible an exhaustive inquiry into the subject under consideration. First in importance are those from Alaska, Kodiak, and the Aleutian Islands ; second, those from pre-Columbian burial grounds in Peru ; and third, those from California, the Pueblo region, and Florida.

The data to be given must, however, be prefaced by certain precautions. The difficulties of these examinations have already been mentioned in part, but there are still others. The materials come largely from old burial grounds, and in these there is generally a large predominance of elderly and old people with scarcity of the young. Many of the skulls from such burials are more or less damaged ; in the old, various teeth have been lost through disease and the alveolar processes were altered, and most of the skulls in the earlier collections are without lower jaws.

Notwithstanding all this, the diagnosis of the willful removal of one or more of the front teeth for other than curative purposes is fairly easy and safe, provided there is a sufficient number of specimens. The criteria are, it may be restated, the loss of such teeth from dentures in which the neighboring teeth show no signs of disease or injury ; the limitation of the loss, in most cases, to the incisors, and in all instances to the teeth seen in such openings of the mouth as in laughter ; the symmetry of the loss ; the occasional presence of a similar loss in the two jaws ; the repetition of the loss of the same dental elements in a group ; in general, in adult skulls, the long period that had evidently elapsed since the extraction ; and the similarity of the losses as well as of the defects they left, to losses and defects in peoples known to practice or to have practiced tooth ablation for ritual purposes.

In the data given in this paper, only those cases are included in which I could be fairly confident that the loss of the teeth in question was old, was not due to an ascertainable injury, and was not, in all probability, due to disease.

It should be said once more, however, that the data to be presented here cannot have any claim to precision. Correct records would only be possible on a series of well-preserved and complete skulls of young adults. Owing to the elimination of uncertain cases and of most of the aged, the data are doubtless below realities. Particularly is this so in the Peruvians, where there were many old, and where, owing to absence of the lower jaws, the corroborative evidence of these was wanting. In the Siberian skulls, too, the mandibles were mostly missing, but from Alaska and the Aleutians there were many complete skulls and skeletons.

It will doubtless be asked why these mutilations in Siberia and particularly in America have not been reported before. The answer in part has already been given; it is that in modern Indians and Eskimo the practice has failed to be observed; that in the skulls of some American groups, where the collections are small, such mutilations appear to be absent; that, aside from Kodiak and the Aleutian Islands where the evidence has but recently come to light, and aside from the Peruvian material which has not yet been well studied, the instances of the practice are limited and the evidence, owing to lack of direct attention to the matter, has been misunderstood or overlooked. It is very probable that when there are ample cranial collections from elsewhere in America, the practice will be found to have been even more extended than would appear from present observations.

Notwithstanding all the difficulties of the subject, there is ample evidence that noncurative removal of some to all of the front teeth has been a widespread procedure since neolithic times in northern Asia, and since the oldest known times in America; that it was practiced, according to the indications, not in early childhood but during adolescence; that it extended to both sexes, though not entirely equally, tending to predominate in the males; that there was large latitude and individuality as to the dental units removed and their number; and that it shows features indicating strongly that it was essentially a ritual, sacrificial observance.

The presentation of the facts in concise form is itself not easy. It will be simplest to show the records of the cases that could confidently be diagnosed as those of early and noncurative ablation, as given in the records, with each case representing a skull, with or without the lower jaw. Cases where the mandible was present and ablation existed in both jaws will be given individually. The percentages under the conditions will certainly be more or less below the realities. In the abstract chart, to make comparisons more feasible, the data will be only those on the upper jaws.

SIBERIA

Neolithic (Irkutsk District)

Materials: 66 adult skulls; 40 male, 26 female.	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors..........................	5	...	...	...

No doubles (i.e., ablations in both jaws).
Percentage of skulls with ablation: Total *7.6;* male *12.5,* female *0.*

Encolithic (*Gorni Altai Oirotskai*)

Materials: 8 adult skulls; 7 male, 1 female.

	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors...........................	I	...	...	...
Left median incisor...........................	...	...	I	...

No doubles.

Percentage of skulls with ablation: Total *25.0.*

Samoyeds

Materials: 21 adult skulls (no lower jaws); 12 male, 9 female.

	Male	Female
Early ablation of:		
Both median incisors..	2	I

Percentage of skulls with ablation: Total *14.3.*

Voguls

Materials: 45 adult skulls (no lower jaws); 18 male, 27 female.

	Male	Female
Early ablation of:		
Both median incisors...............................	...	I
Right median incisor..	...	3

Percentage of skulls with ablation: Total *8.9;* male *0,* female *14.8.*

Ostiaks (*Little Ob River*)

Materials: 206 adult skulls; 98 male, 108 female.

	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors...........................	2	I	I	I
Right median incisor...........................	3	...	4	...
Left median incisor...........................	2	...	4	...
Both median and lateral incisors...............	I	...	...	...
Left lateral incisor...........................	I	...	I	...
All incisors and right canine....................	...	...	I	...
Both right incisors.............................	...	...	I	...
Both left incisors.............................	I	...	...	...
Right lateral and both left incisors............	I	...	...	...
All incisors	I	I	2	...
Both right and left upper median and lower left median incisors	I		...	
Left upper and both lateral lower incisors......	I		...	

Two doubles.

Percentage of skulls with ablation: Total *15.0;* male *16.3,* female *13.9.*

Giliaks (Sachalin Island)

Materials: 23 adult skulls; 9 male, 14 female.

	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors..........................	·I	...	...	...
All upper incisors.............................	...	...	I	...

Most without lower jaw.
Percentage of skulls with ablation: Total *8.7.*

Ulchi (Amur River)

Materials: 24 adult skulls (most without lower jaws) ; 9 male, 15 female.

	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Right median incisor..........................	I	...	I	...
Left median incisor...........................	...	...	I	...

Percentage of skulls with ablation: Total *16.7.*

Yakuts

Materials: 7 male skulls (without lower jaws).

Early ablation of:
All incisors I

Percentage of skulls with ablation: Total *14.3.*

Chukchi

Materials: 116 adult skulls (few with lower jaws) ; 49 male, 67 female.

	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors..........................	...	I	...	...
Right median incisor..........................	...	...	I	...
Left median incisor...........................	I	...	I	...
Both right incisors............................	I	...	...	...
Both left incisors.............................	I	...	...	...
All incisors	I	...	I	...

Percentage of skulls with ablation: Total *6.9;* male *10.2,* female *4.5.*

Mongols

Materials: 179 adult skulls; 106 male (40 with lower jaw), 73 female (29 with lower jaw); 56 separate lower jaws.

SKULLS WITH LOWER JAW:

	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors...........................	I	I	...	I
Right median incisor...........................	I	...	...	...
Left median incisor...........................	I	...	...	...
Right lateral incisor..........................	I	...	...	...
Left lateral incisor...........................	...	...	I	...
All incisors	I	...	...	...
All incisors and canines.......................	...	...	...	I
Most upper front teeth.........................	I	...	...	...
Both right upper incisors, right canine, and both right premolars	I	...	...	...
Both left upper incisors and left lateral lower incisor	I		...	
Both upper median incisors and both lower canines.	I		...	
Both upper median incisors, lower probable, but broken	I		...	
Upper ? (all lost), both lower median incisors..	2		...	
Right upper and right lower median incisors....	I		...	
Right upper median with both lower median and right lateral incisors.........................	I		...	
Both upper lateral and left lower median incisors.	...		I	

SKULLS WITHOUT LOWER JAW:

Early ablation of:	Male	Female
Both upper median incisors.................................	2	I
Right upper median incisor.................................	3	...
Left median incisor...	2	4
Both left incisors...	I	...
All incisors	3	...
Both median and right lateral incisors.......................	2	...
Both median and left lateral incisors........................	2	...

Percentage of skulls with ablation: Total *21.2;* male *28.3,* female *11.0.*

SEPARATE LOWER JAWS:

Early ablation of:	Male	Female
Right lower median incisor....................................	I	...
Both median incisors and right lateral incisors.................	I	...
Both median incisors and left lateral incisors..................	I	...
Both median incisors..	...	I
Both median and left lateral incisors..........................	...	I

Percentage of separate lower jaws with ablation: Total *8.9.*

Buriats

Materials: 54 adult skulls; 28 male (10 with lower jaw), 26 female (8 with lower jaw).

SKULLS WITH LOWER JAW:

Early ablation of:	Male	Female
Both upper lateral and both lower median incisors............. ...		I
Both upper median, right upper lateral, and both lower median incisors		I
All but 3 upper teeth, all lower incisors........................ ...		I

SKULLS WITHOUT LOWER JAW:

Early ablation of:	Male	Female
Both median incisors..	I	3
Right median incisor.. ...		2
Left lateral incisor... ...		I
Right median and lateral incisors.............................	I	...
Both median incisors (and perhaps also right lateral and both canines)		I

Percentage of skulls without lower jaw with ablation: Total *40.*—; male *18.*—, female *51.43.*

AMERICA

Eskimo (St. Lawrence Island)

Materials: 443 adult skulls; 239 male, 204 female; 94 separate lower jaws.

SKULLS WITH ABLATION IN ONE JAW ONLY:

Early Ablation of:	Male Upper	Male Lower	Female Upper	Female Lower
Both median incisors..........................	I	I	2	2
Right median incisor...........................	2	...	...	...
Left median incisor............................	4	...	I	'I
Both lateral incisors........................... ...		...	...	...
Left lateral incisor............................ ...		...	I	...
Both left incisors.............................	3	...	2	...
All incisors	I	...	...	...
Both median and left lateral incisors............	I	...	...	...
Both right incisors and right anterior premolar..	I	...	...	...
Both upper left incisors, left canine, and right anterior premolar	I	...	...	...
Right lateral incisor and canine................	I	...	...	...
Both left incisor and probably right posterior premolar	I	...	...	...
All right incisors, canine, and premolars........ ...		...	I	...
All incisors and right anterior premolar........	I	...	...	...
Both median with right upper incisors, and seemingly both premolars..................... ...		...	I	...

No doubles.

Percentage of skulls with ablation: Total *6.6;* male *7.5,* female *5.4.*

SEPARATE LOWER JAWS:

Early ablation of:	Male	Female
Both median incisors..	3	4
Right median incisor..	...	I
Left median incisor...	I	I
Both lateral incisors.......................................	...	I
Both median and right lateral incisors......................	I	I
Both median and left lateral incisors.......................	...	2
Both incisors left side.....................................	...	I
All incisors	...	I
Both median incisors and both left premolars................	...	I

Percentage of separate lower jaws with ablation: *19.2.*

Eskimo (*Alaska, outside of St. Lawrence Island*)

Materials: 383 adult skulls; 160 male, 223 female.

SKULLS WITH ABLATION IN ONE JAW ONLY:	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors...........................	...	I	2	5
Left median incisors...........................	...	...	I	I
Both median and left lateral incisors..........	2	...	...	...
Both left incisors.............................	...	...	I	...
Right median and left lateral incisors.........	I	...	...	...
Both left upper incisors and lateral incisors....	I	...	...	...
Left lateral incisor to M2 incl................	...	...	...	I
All incisors	...	...	2	...

Percentage of skulls with ablation: Total *4.7;* male *3.1,* female *5.8.*

Eskimo (*Children and Adolescents*)

Materials: 137 skulls and 112 separate lower jaws.

U. S. N. M. No.	Condition	Ablation
242,823..........both M2 fully erupted		All upper incisors
♀ 345,728..........M3 left ½, right ⅘ erupted		Max.: Both median incisors Mand.: Both median incisors

Aleuts

Materials: 281 adult skulls; 135 male, 136 female; 68 separate lower jaws.

SKULLS WITH ABLATION IN ONE JAW ONLY:	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors...........................	8	...	5	...
Right median incisor...........................	2	...	8	...
Left median incisor............................	6	...	I	I
Both lateral incisors..........................	2	...	I	...
Left lateral incisor...........................	...	...	...	I
Both median and right lateral incisors.........	2	...	2	...
Both median and lateral incisors...............	I	...	...	...
Left incisor	I	...	...	...
Left median and both right incisors............	...	...	...	I
Both median and left lateral incisors, left canine and both bicuspids...........................	I	...	...	...
All incisors	2	2	2	...
All incisors and all premolars.................	...	...	I	...

Skulls With Ablation in Both Jaws: Male Female

  All upper and both lower median incisors...................... I   ...

Percentage of skulls with ablation: Total *18.2;* male *20.7,* female *16.9.*

Separate Lower Jaws:

Early ablation of: Male Female

  Both median incisors... I   ...
  Both left incisors and right lateral incisor and canine............ I   ...

Percentage of separate lower jaws with ablation: *3.0.*

Pre-Aleuts

Materials: 93 adult skulls; 49 male, 44 female.

Skulls With Ablation in One Jaw Only:	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors...........................	5	1	5	4
Right median incisor...........................	3	...	2	1
Left median incisor...............................	1	...	1	...
Both lateral incisors...........................	3	...	...	...
Both median and left lateral incisors............	1	...	1	...
Left median and both lateral incisors.............	...	...	...	1
Right incisor	3	...	...	...
Both median and lateral incisors.................	...	...	...	1
Left canine	1	...	...	...
All incisors	2	...	1	...
All teeth	1	...	...	...

Skulls With Ablation in Both Jaws:

Early ablation of: Male Female

  Both upper and both lower median incisors..................... ...   1
  Both upper median and left lower median incisors............... 1   ...
  All upper and both lower median incisors...................... ...   1
  Right upper median and left lower median incisors............. 2   ...
  Left upper median, both lower median and left lower lateral
    incisors   1
  Right upper lateral and both lower median incisors............. ...   1
  Left upper lateral and both right upper incisors with right lower
    median incisor   1
  All upper and lower incisors.................................. ...   1
  All upper teeth on left to molars; right lower incisors........... ...   1

Percentage of skulls with ablation: Total *52.7;* male *49.0,* female *56.8.*

Koniags (*Kodiak Island*)

Materials: 83 adult skulls, 51 male, 32 female.

Skulls With Ablation in One Jaw Only:	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Right median incisor...........................	1	...	...	...

SKULLS WITH ABLATION IN BOTH JAWS:

Early ablation of: Male Female
    Right upper median incisor and all lower incisors as well as lower
       left premolars   I   ...

Percentage of skulls with ablations: Total *2.4;* male *3.9,* female *0.*

Pre-Koniags (*Kodiak Island*)

Materials: 200 adult skulls; 67 male, 133 female.

SKULLS WITH ABLATION IN ONE JAW ONLY:	Male		Female	
Early ablation of:	Upper	Lower	Upper	Lower
Both median incisors............................	3	2	3	2
Left median incisor..............................	...	...	I	...
Left upper incisor................................	...	...	I	...
Right median and lateral incisors...............	...	...	I	...
Both median and both lateral incisors..........	...	...	...	I
All incisors except left lateral..................	...	...	I	...
Right canine	...	...	...	I
All incisors	...	...	I	2

SKULLS WITH ABLATION IN BOTH JAWS:

Early ablation of: Male Female
    Both upper and both lower median incisors..................... | ... | I
    Upper median and lower median with lower left lateral incisors.. | I | ...
    Right teeth .... | I | ...

Percentage of skulls with ablation: Total *11.—;* male *10.4,* female *11.3.*

Alaska Indians

Materials: 85 adult skulls; 41 male (32 with lower jaw), 44 female (37 with
    lower jaw); 2 separate lower jaws.

Early ablation of frontal teeth:
    Male: None
    Female:

        a. Holy Cross (Yukon) ... Both right upper incisors
                        ⎧ Upper jaw: all incisors and right an-
        b. Holy Cross ....⎨   terior premolar
                        ⎩ Lower jaw: none
        c. Shageluk ....⎰ Upper jaw: all incisors
                        ⎱ Lower jaw: none

Percentage of skulls with ablation: Total *3.5;* male *0,* female *6.8.*

SEPARATE LOWER JAWS:

    Male: Prince William Sound....Right lateral incisor, canine and anterior
                               premolar; left canine and anterior pre-
                               molar
    Sex uncertain: Knight Island...Right median incisor and left canine (un-
                               less congenitally absent)

California [a] Indians

Materials: 648 adult skulls; 337 male (170 with lower jaw), 311 female (138 with lower jaw).

Early ablation of:	Male		Female	
	Upper	Lower	Upper	Lower
Both median incisors.............................	1	...	4	1
Right median incisor............................	3	...	5	...
Left median incisor..............................	3	...	1	...
Right lateral incisor............................	...	1	... .	...
Left lateral incisor.............................	...	1	1	...
Both median and right lateral incisors............	...	...	1	...
Both left incisors...............................	1	...	1	...
All incisors	...	...	1	...
All incisors and apparently also right canine....	1	...	1	...
Both median incisors and probably all premolars..	1	...	...	...
Both median incisors with left lateral incisor and probably both left premolars.................	1	...	...	...
Left median incisor and both left premolars..... ...	...	...	1	...
Right lateral incisor and both anterior premolars. ...	...	1	...	...
All incisors, both canines, and both anterior premolars	...	...	1	...
All premolars	...	...	...	1

Percentage of skulls with ablation: Total *5.1;* male *4.2,* female *6.1.*

SEPARATE LOWER JAWS (540; 10 with ablation) :
Both median incisors......................... 6
Left median incisor............................ 2
Both median and right lateral incisors........ 1
Both median with left lateral incisor and right anterior premolars 1

Percentage of separate lower jaws with ablation: *5.4.*

[a] Numerous localities; both mainland and islands; none recent.

Pueblos (*prehistoric, New Mexico and Arizona*)

Materials: Adult skulls, 500; 233 male (137 with lower jaw), 267 female (138 with lower jaw).

Early ablation of:	Male		Female	
	Upper	Lower	Upper	Lower
Both median incisors............................	2	1	1	3
Right median incisor.............................	1	...	1	...
Left median incisor.............................	5	...	...	1
Both median and right lateral incisors............	...	...	...	...
Right lateral incisor............................	...	...	1	...
Both lateral incisors............................	...	...	1	...
Both right incisors..............................	...	1	4	...
Both left incisors...............................	1	...	...	1
Right median and left lateral incisors............	...	...	1	...
Left lateral incisor and canine...................	...	...	1	...

Ablation in both jaws only in 1 male and 1 female.
Percentage of skulls with ablation: Total *5.6;* male *5.1,* female *6.0.*

Apache

Materials: 32 adult skulls; 20 male (17 with lower jaw), 12 female (3 with lower jaw); 17 separate lower jaws.

Early ablation of frontal teeth:
 Male:

1. San Carlos, Ariz..... { Upper jaw: left median incisor and right anterior premolar
         Lower jaw: right median incisor

2. Yuma Apache .... { All upper incisors
          Lower jaw absent

 Female:

a. San Carlos, Ariz..... { Upper jaw: all incisors
          Lower jaw: right median incisor

b. White River, Ariz.[a]... { Upper jaw: section of alveolar process with all incisors, right canine and right anterior premolar, cut out
          Lower jaw: absent

Percentage of skulls with ablation: Total *12.5;* male *10.0,* female *16.7.*

SEPARATE LOWER JAWS:
  San Carlos, Ariz............Left lateral incisor

 [a] This skull presents a unique lesion (pl. 5). A large portion of the alveolar process in the front has been cleanly cut off, together with the teeth, and there was a normal healing. This is a unique case and difficult of exact explanation. But it appears certain that the operation was not performed for any pathological condition.

Sioux (19th century)

Materials: 94 adult skulls; 53 male, 41 female. Skulls with lower jaws; 35 male, 31 female.

Early ablation of frontal teeth:
 Male:

1. Both upper median incisors (lower jaw absent)
2. Both upper left incisors (none in lower jaw)
3. Both upper lateral incisors (lower jaw absent)
4. Right upper median and left lateral incisors, with several front teeth in lower jaw
5. Both upper lateral and right lower median incisors
6. Left upper lateral incisor (lower jaw absent)
7. Left upper lateral incisor (lower jaw absent)
8. Left upper lateral incisor (none in lower jaw)

 Female:

a. Both upper median incisors (lower jaw absent)
b. Left upper median incisors (lower jaw absent)

Ablation in both jaws: 2.

Dakotas (older burials)

Materials: 112 adult skulls; 63 male (46 with lower jaw), 49 female (40 with lower jaw); 14 separate lower jaws.

Early ablation of frontal teeth:

Male:

Both upper median incisors (no lower).................... 2
Left upper median incisor (no lower)..................... 2
Left upper median incisor (lower jaw absent)............ 1
Both median and left upper lateral incisors (no lower)..... 2

Female:

Both upper median incisors (no lower)................... 1
Both upper median incisors (lower jaw absent)............ 1
Right upper median incisor (left median incisor).......... 1
Left upper median incisor (no lower)..................... 1
No upper (both lower left incisors)...................... 1

SEPARATE LOWER JAWS:

Left median incisor..................................... 1

Ohio Mounds (prehistoric)

Materials: 204 adult skulls; 112 male, 92 female; 83 separate lower jaws.

Early ablation of frontal teeth:

Male:

1. Both lower median incisors (no upper)
2. Both upper median incisors (lower ?)
3. All upper incisors (no lower)
4. Right upper median incisor (no lower)
5. Left upper median incisor (no lower)
6. Both upper median and right lateral incisors (lower ?)
7. Both right and left lateral incisors (no lower)
8. All upper and both lower median incisors

Female:

a. Both upper and both lower median incisors
b. Right upper median incisor (lower ?)

Percentage of skulls with ablation: Total *4.9;* male *7.1* (7 upper, 1 both upper and lower), female *2.2* (1 upper, 1 both upper and lower).

SEPARATE LOWER JAWS:

Male:

Right median incisor.................................... 3
Both median incisors.................................... 1

Female:

Both median incisors.................................... 1
All incisors 1

Percentage of separate lower jaws with ablation: *9.5.*

Kentucky Indians (pre-White)

Materials: 107 adult skulls; 59 male (29 with lower jaw), 48 female (24 with lower jaw) ; 5 separate lower jaws.

Early ablation of frontal teeth:

Male:

1. Upper jaw: all incisors
   Lower jaw: none
2. Upper jaw: left median incisor
   Lower jaw: none
3. Upper jaw: left median incisor
   Lower jaw: none
4. Upper jaw: both left and right lateral incisors
   Lower jaw: right median incisor

Female:

a. Upper jaw: both lateral incisors
   Lower jaw: left median incisor

Percentage of skulls with ablation: Total *4.7;* male *6.8* (3 upper alone, 1 both upper and lower), female *2.1.*

Iroquois and New York Algonquins

Materials: 26 adult skulls; 12 male (10 with lower jaw), 14 female (11 with lower jaw).

Early ablation of frontal teeth:

Male: None

Female: [a]

a. Staten Island .... { Upper jaw: all incisors and canines
                          { Lower jaw absent

b. New York .... { Upper jaw: all incisors, canines, and prob-
                       { ably premolars
                       { Lower jaw: none (as far as discernible)

Percentage of skulls with ablation: Female *14.0,* both upper (lower ?).

[a] Both specimens probably Algonquin, both elderly (but not *old*), conditions not as clear as desirable, caries and numerous teeth lost; but main facts seem definite.

Hurons (Canada)

Materials: 21 adult skulls; 11 male (no lower jaws), 10 female (2 with lower jaw) ; 2 separate lower jaws.

No ablation.

Potomac River Algonquins (prehistoric and earliest historic)

Materials: [a] 365 adult skulls; 171 male, 194 female; 353 separate lower jaws; 57 skulls of children.

Early ablation of:	Male [b] Upper	Male [b] Lower	Female [b] Upper	Female [b] Lower
Both median incisors	I	...	I	5
Right median incisor	...	...	I	...
Left median incisor	...	...	2	...
Both median and right lateral incisors	3	...	2	2
Both median and left lateral incisors	...	I	I	2
Both incisors left side	I	...	...	...
Left lateral incisor	I	...	I	...
All incisors	...	...	I	...
All incisors and right canine	...	...	...	I
All incisors, canines, and anterior premolars	I	...	...	...

Percentage of skulls with ablation: Total *4.4;* male *4.1,* female *4.6.*

SEPARATE LOWER JAWS: [b]

Both median incisors	6
Left median incisor	I
Both median and left lateral incisors	I
All incisors	4

Percentage of separate lower jaws with ablation: *3.4.*

[a] Very many damaged, both skulls and jaws.
[b] In a number of others there is evidence of early ablation of front teeth, but the bones are in such bad condition that definite determination is impossible.

Florida Indians (old)

Materials: 663 adult skulls; 356 male (132 with lower jaw), 317 female (97 with lower jaw); 301 separate lower jaws.

Early ablation of:	Male Upper	Male Lower	Female Upper	Female Lower
Both median incisors	3	5	2	3
Right median incisor	2	I	...	...
Left median incisor	2	...	4	...
Both median and right lateral incisors	...	...	...	I
All incisors	I	...	...	...
All upper and both lower median incisors		I	...	
Both median upper and right median lower incisors		I	...	
Left upper and both lower median incisors		I	...	
Right upper lateral incisor and right upper canine		I	...	
All upper and both lower median incisors		I	...	

Percentage of skulls with ablation: Total *4.4;* male *5.3,* female *3.1.*

Separate Lower Jaws:

Early ablation of:	Male	Female
Both median incisors..	3	3
Right median incisor...	2	...
Left median incisor..	1	...
All incisors and right canine.................................	1	...

Percentage of separate lower jaws with ablation: *3.4.*

Indians of Mexico

Materials: 52 adult skulls; 24 male (4 with lower jaw), 28 female (3 with lower jaw) ; 18 separate lower jaws.

Early ablation of frontal teeth:
  Male:

1. San Luis Potosi...... { Upper jaw: all incisors and probably left canine / Lower jaw absent

2. Valley of Mexico..... { Upper jaw: all incisors and canines / Lower jaw: none

3. Maya, Yucatan ...... { Probably several upper front teeth—uncertain due to loss of back teeth / Lower jaw absent

  Female:

a. San Luis Potosi...... { Upper jaw: both right incisors / Lower jaw: absent

b. Valley of Mexico..... { Upper jaw: left median incisor / Lower jaw: none

Percentage of skulls with ablation: Total *9.6;* male *12.8,* all upper (lower ?) ; female *7.1,* all upper.

Separate Lower Jaws:

  Male:
    San Luis Potosi...........................Both median incisors

  Child of about 12 years:
    San Luis Potosi (both M2 fully erupted)....Both median incisors

Percentage of separate lower jaws with ablation: *11.1.*

Indians of Old Peru

Materials: 3,600 adult skulls without lower jaws; 1,780 male, 1,820 female.

Early ablation of:	Male	Female
Both median incisors..	16	26
Right median incisor.......................................	7	10
Left median incisor..	4	13
Right lateral incisor.......................................	1	...
Left lateral incisor..	...	2
Both lateral incisors.......................................	...	1
Right median and left lateral incisors........................	...	1
Left median and right lateral incisors........................	...	1
Both median and right lateral incisors.......................	3	6
Both median and left lateral incisors........................	5	8
Right median and both lateral incisors.......................	...	1
Both right incisors..	...	1
Both left incisors...	2	3
All incisors	3	7
All incisors and both canines...............................	1	5
All incisors and right canine...............................	...	5
All incisors and left canine................................	...	1
Left lateral incisor and left canine..........................	1	...
All incisors and premolar..................................	2	...
Both right incisors with right canine and right anterior premolar.	...	1
Both right incisors with left canine and left anterior premolar...	1	...
Both left incisors with right lateral incisors, canine and anterior premolar	1	...
All incisors, both right premolars and left posterior premolar....	1	...
Right median, with both lateral incisors and left canine..........	...	1
All incisors, canines, and anterior premolars..................	...	1
Right lateral incisors and both right premolars...............	...	1

Percentage of skulls with ablation in upper jaw (lower ?): Total *4.9;* male *2.7,* female *5.2.*

SEPARATE LOWER JAWS:

Early ablation of:	Male	Female
Both median incisors..	4	5
Right median incisor..	...	1
Left median incisor...	...	4
Left lateral incisor...	...	1
Both median and right lateral incisors........................	1	1
Right median and both lateral incisors.......................	...	1
All incisors	3	1
All incisors and right canine................................	1	...

Percentage of separate jaws with ablation: *5.3.*

ABSTRACT OF NEW DATA

Percentages of ablation in the upper jaw, disregarding the lower jaw

Siberia

People	Skulls examined			Early ablation of front teeth in maxillae					
	Total	Male	Female	Total	Male	Female	% total	% male	% female
Neolithic, Irkutsk District ...	66	40	26	(5)	(5)	(0)	7.6	12.5	0
Encolithic, Gorni Altai	8	7	1	(2)	(1)	(1)	25.0	...	...
Samoyeds	21	12	9	(3)	(2)	(1)	14.3	...	...
Voguls	45	18	27	(4)	(0)	(4)	8.9	0	14.8
Ostiaks	206	98	108	(28)	(14)	(14)	13.6	14.3	13.0
Giliaks	23	9	14	(2)	(1)	(1)	8.7	...	...
Ulchi	24	9	15	(3)	(1)	(2)	16.7	...	...
Yakuts	7	7	...	(1)	(1)	...	14.3	...	...
Chukchi	116	49	67	(7)	(4)	(3)	6.0	8.2	4.4
Mongols	179	106	73	(36)	(29)	(7)	20.1	27.4	9.6
Buriats	54	28	26	(12)	(2)	(10)	22.2	7.1	38.5

America

People	Skulls examined			Early ablation of front teeth in maxillae					
	Total	Male	Female	Total	Male	Female	% total	% male	% female
Eskimo (St. Lawrence Island)	443	239	204	25	17	8	5.6	7.1	3.9
Eskimo (other)	383	160	223	10	4	6	2.6	2.5	2.7
Aleuts	281	135	136	45	25	20	16.0	18.5	14.7
Pre-Aleuts	93	49	44	40	23	17	43.0	51.1	38.6
Koniags (Kodiak) ..	83	51	32	2	2	...	2.4	3.9	0
Pre-Koniags (Kodiak)	200	67	133	14	5	9	7.0	7.5	6.8
Alaska Indians	85	41	44	3	...	3	3.5	0	6.8
California Indians...	648	337	311	28	11	17	4.3	3.2	5.5
Pueblos	500	233	267	19	9	10	3.8	3.9	3.7
Apache	32	20	12	4	2	2	12.5	(10.0)	(16.7)
Sioux	94	53	41	10	8	2	10.6	15.1	4.9
Dakotas (older burials)	112	63	49	12	7	5	10.7	11.1	10.2
Ohio Mounds	204	112	92	9	7	2	4.4	6.2	2.2
Kentucky Indians (pre-White)	107	59	48	5	4	1	4.7	6.8	2.1
Iroquois and New York Algonquins..	28	12	14	2	0	2	14.0	(0)	(14.0)
Potomac River Algonquins	365	171	194	16	7	9	4.4	4.1	4.6
Florida Indians	663	356	317	19	13	6	2.9	3.7	1.9
Indians of Mexico...	52	24	28	5	3	2	9.6	12.5	7.1
Indians of Old Peru	3,600	1,780	1,820	143	48	95	4.0	2.7	5.2

DISCUSSION AND SUMMARY

Cranial evidence shows that ritual ablation of one or more of the front teeth at puberty, and possibly other forms of noncurative removal of such teeth, were practiced in parts of the Old World since upper paleolithic and neolithic times. Ritual ablations at puberty are still common in Africa and Australia.

The data brought forth on the preceding pages show definitely that the practice of removing some of the front teeth was widely spread from prehistoric to fairly recent times over both Siberia and America. In Siberia and Japan it existed from the neolithic period, if not earlier, and was in all probability brought by the migrants of that period to the American continent. How it came to Siberia and Japan is as yet doubtful; it may have reached there over southwestern Asia, or from the south over Japan, or from both directions. In view of the peculiarity and complexity of the practice it seems improbable that it could have arisen independently in any of the regions here under consideration.

Such removals in some places were associated, but only very exceptionally in the same individuals, with filing of the front teeth; the filing however is a separate practice with different significance, and in a large majority of cases the removals existed alone and independently.

In northern Asia both ablation and filing are known to have been in vogue among the prehistoric Aino, and in America filing of teeth has been reported from parts of old Mexico; but there was little knowledge hitherto of noncurative removals of teeth in Siberia and among the American Indians and Eskimo. Examinations by the writer, with this point in view, of large Siberian and American cranial collections has shown that noncurative and in most cases evidently ritual ablation of some or all the front teeth has in older times been widespread in both these great regions. In pre-Columbian America, in fact, it appears to have been almost, if not quite, universal.

The removal of the teeth, according to all indications, took place early in life, but not in childhood—the numerous skulls of children up to 10 years of age in our collection show no case of the ablation. In general, it seems, the removal of the teeth was done during adolescence, which strongly suggests association with puberty and its initiations. From this life-period, regrettably, specimens in all collections are very scarce, so that it is impossible to assemble an exact demonstration of the facts.

As to the teeth removed, there was a wide variety. The same fact had been observed in the neolithic Aino. In no one group was there but a single type of the removal, though predominance in one way or another was common. The teeth most frequently removed were one or more of the incisors, especially those of the upper jaw; but in some cases the ablation was more extensive, including even the canines and some of the premolars. And the upper teeth on the whole suffered more than the lower.

The ablations were done generally in both sexes, though mostly they are found in a more or less larger proportion of the males. And in none of the Siberian or American groups did the practice affect all persons. There was evidently some selection. In the American tribes, barring the Aleutian Islands, the proportion of persons thus treated was always small to moderate, seldom reaching over 10 percent of the adult total.

The practice differed in the various tribes, the removal of certain teeth having evidently been more favored in some groups than in others; but there was no rigid rule in this respect, and every group presents a number of individual variations in the removals.

The strong probability is that in general, or at least in a majority of the cases, the ablations both in Siberia and America were of a ritual nature. It would be difficult to attribute any material proportion of them either to disease or to accident; and the evidence, especially the variety of the removals, speaks against any large proportion of the losses of the teeth here reported being due to branding or to punishment.

Cases of loss of teeth from accidents, punishment, or for simple branding, cannot be clearly distinguished from the ritual ablations; but the nature of the losses, their sex distribution, the indications that they occurred early in life, and the presence or absence of other lesions, are helpful in the diagnosis.

The actual ways of removal of the teeth in all probability differed, including knocking out, prying, and especially pulling with sinews, or a combination of these efforts. The general lesion produced on the alveolar process was the breaking through and subsequent loss of the labial wall of the alveolus from which the tooth had been removed.

The meaning of the ritual ablation could only have been sacrificial, with secondarily a test of endurance. The practice falls into the same class with circumcision and could have had no connection, it would seem, with decorative, cosmetic, or simple torture mutilations.

The removals were undoubtedly practiced by other persons, relatives or shamans. The lesions, where still visible, indicate a good deal of resemblance in the essentials of the practices with considerable diversity in details. The teeth, in both Siberia and America, were probably more often pulled or pried out, than knocked out, with the breaking open of the labial wall of the alveolus, while the lingual wall remained unaffected. Generally, the removal was very successful and the subsequent healing without incident, but rarely a root of the tooth was broken, or the damage to the alveolar process was more extensive—but even in these cases there was a good healing. In general the removal was followed by an obliteration of the alveolus and absorption with marked thinning of the process, so that the same ended in a sharp border. In some cases the space left by the removal remained evidently but little affected; in most, however, it also shrank laterally. The teeth on the sides of the space either inclined to or approached each other, or both. The teeth opposite the lesion extruded somewhat, but were not lost. In unilateral ablations, especially where they affected more than one tooth, the alveolar process in front occasionally became asymmetric.

The extraction, if of but one tooth, caused presumably but little inconvenience; but where more than one tooth was removed both chewing and speech, and even the form of the lips and the neighboring parts, must have been more or less affected.

The ablations, curiously, though differing considerably in frequency in different groups, were never universal. In most of the tribes or localities they were in fact rather rare, affecting but a few percent of the individuals. There evidently was some selection—based perhaps on clan or other form of social organization.

In neolithic Japan and possibly in parts of pre-Columbian Mexico, the practice of ablation was contemporary with tooth filing; but in a large majority of the cases both in northern Asia and in America there is no such association.

The removals of more than one of the front teeth had such an effect on the structure and dimensions of the alveolar processes that they affected, more or less, the anthropometric determinations on the face. This interference calls for careful consideration and appraisal on the part of the measurer, and in cases makes the measurement of the height of the face quite impossible. The results of the practice constitute another nuisance with which American and Siberian craniometry will have to contend.

The similarity, and to a large extent contemporaneity, of this complex ritual practice forms one more link that connects the Asiatic and American native peoples. In America the practice was evidently later, having been brought over by the immigrant Siberian groups. Just when and whence it came into Siberia, is still a matter of conjecture; it was there certainly since neolithic times and may have been there even earlier.

ILLUSTRATIONS

The accompanying illustrations show a number of variants of the lesions produced by the ablations.

Upper:
    Left, Old Pueblo, New Mexico, male, elderly. U.S.N.M. No. 263063.
    Right, Old Zuni, male, about 24 years. U.S.N.M. No. 314279.
Middle:
    Left, Eskimo, St. Lawrence Island, female, adolescent. U.S.N.M. No. 24283.
    Right, Eskimo, St. Lawrence Island, male, about 22 years. U.S.N.M. No. 368270.
Lower:
    Left, Yukon Indian, female, about 25 years. U.S.N.M. No. 332520.
    Right, Ohio Mound, male, about 45 years. U.S.N.M. No. 328829.

Upper:
    Left, Pueblo (Old Zuni), male, about 45 years. U.S.N.M. No. 314322.
    Right, Eskimo, St. Lawrence Island, male, about 50 years. U.S.N.M. No. 279525.
Middle:
    Left, Pre-Aleut, male, elderly. U.S.N.M. No. 242913.
    Right, Alaska Indian, female, elderly. U.S.N.M. No. 345353.
Lower:
    Left, Pre-Aleut, male, elderly. U.S.N.M. No. 243974.
    Right, Algonkin, Md., female, about 40 years. Provis. No. 2/2.
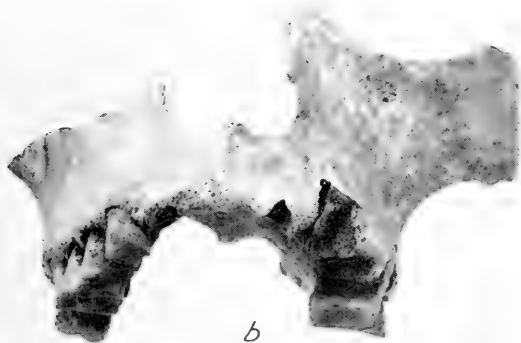
a, Old Zuni, female, elderly. U.S.N.M. No. 308670.
b, Florida, male, elderly.
c, Florida, male, elderly. U.S.N.M. No. 352100.

Upper:
    Left, Aleut, male, elderly. U.S.N.M. No. 17479.
    Right, Prince William Sound, Alaska, male, elderly. U.S.N.M. No. 332020.
Second row:
    Left, St. Lawrence Island, female, elderly. U.S.N.M. No. 364703.
    Right, Alaska Indian, male, elderly. U.S.N.M. No. 262170.
Third row:
    Left, Old Zuni, male, about 30 years. U.S.N.M. No. 308620.
    Right, Eskimo, St. Lawrence Island, male, about 30 years. U.S.N.M. No. 352422.
Lower:
    Left, Eskimo, St. Lawrence Island, female, about 50 years. U.S.N.M. No. 242766.
    Right, Florida, female, about 50 years. U.S.N.M. No. 352077.

Apache, female about 30 years, showing cutting off of frontal part of upper alveolar process with teeth.
U.S.N.M. No. 228044.

A CHECK-LIST OF THE FOSSIL BIRDS
OF NORTH AMERICA

BY
ALEXANDER WETMORE
Assistant Secretary, Smithsonian Institution

A CHECK-LIST OF THE FOSSIL BIRDS
OF NORTH AMERICA

BY
ALEXANDER WETMORE
Assistant Secretary, Smithsonian Institution

A CHECK-LIST OF THE FOSSIL BIRDS OF NORTH AMERICA

By ALEXANDER WETMORE

Assistant Secretary, Smithsonian Institution

Since publication of the last complete list of the fossil birds of North America, which appeared in the Fourth Edition of the Check-list of North American Birds of the American Ornithologists' Union in October 1931, there have been many changes and additions, both in species found only in fossil state and in modern forms recorded from Pleistocene and (rarely) earlier deposits. This information is widely scattered so that it seems pertinent now to gather it together and to present the entire list again for the use of all who may be interested.

The material that follows is complete so far as records have come to attention to January 1940.

In preparing this paper every species included has been checked carefully against the original records, and data pertaining to geologic distribution have been revised. As in the fourth edition of the A. O. U. Check-list, all modern forms for which there are fossil records have been included. In addition there have been added certain species, such as *Geococcyx conklingi,* that, although from deposits that are possibly Recent in age, are known only from bones, and so do not find a proper place in the list of modern birds. There are also included records of Recent age for such species as *Spizaëtus willetti* and *Coragyps occidentalis* that extend from the Pleistocene into the Recent but that are known only from skeletal remains.

The modern species that occur in the fossil record are distinguished from those not known in living form by the common name and by a suitable phrase in the range. Most of these are listed under specific names without regard to subspecies, since it is not usually practicable to identify geographic races from bones. It is doubtful procedure ordinarily to assume that Pleistocene subspecies were the same as those living in the same region today, and such assumption is made only where there is reasonable certainty of the identification. We know of many extensions of range in the prehistoric period among species of birds, and it is reasonable to suppose that the same has been true among subspecies. It should be remembered therefore

that the specific name in wide-ranging species in which several sub-specific forms are now recognized is used in an inclusive sense, and that in records of *Corvus corax,* for example, there is no intention to imply that the Old World raven has been found in North America. In some cases there is no doubt that two or more subspecies are covered by the fossil record, as with *Bonasa umbellus* whose bones have been found in fossil deposits in Maryland and California.

The list as here published includes records of 165 forms that are still living, and of 184 species recorded only in the extinct state. There are 12 additional forms in a hypothetical list, the status of which is uncertain and which are not included in the tabulation just given.

In checking details for this manuscript and in reading proof I have had the kind assistance of Dr. Hildegarde Howard, Dr. Loye Miller, and Dr. Alden H. Miller, to whom my sincere thanks are due for this friendly assistance.

.

Class AVES. Birds

Subclass NEORNITHES. True Birds

Superorder ODONTOGNATHAE. New World Toothed Birds

Order HESPERORNITHIFORMES. Hesperornithes

Family HESPERORNITHIDAE. Hesperornithes

Genus HESPERORNIS Marsh

Hesperornis Marsh, Amer. Journ. Sci., ser. 3, vol. 3, 1872, p. 360. Type, by monotypy, *Hesperornis regalis* Marsh.

Hesperornis crassipes (Marsh)

Lestornis crassipes Marsh, Amer. Journ. Sci., ser. 3, vol. 11, 1876, p. 509.

Upper Cretaceous (Niobrara): Western Kansas.

Hesperornis montana Shufeldt

Hesperornis montana Shufeldt, Auk, vol. 32, No. 3, July 1915, p. 293, pl. 18, figs. 4, 6, 8, 10, 12.

Upper Cretaceous (Claggett formation): 1 mile above mouth of Dog Creek, Fergus County, Montana.

Hesperornis regalis Marsh

Hesperornis regalis Marsh, Amer. Journ. Sci., ser. 3, vol. 3, 1872, p. 357.

Upper Cretaceous (Niobrara): Smoky Hill River, 20 miles east of Wallace,[1] and Two Mile Creek, Smoky Hill River, Logan County, Kansas.

Genus CONIORNIS Marsh[2]

Coniornis Marsh, Amer. Journ. Sci., ser. 3, vol. 45, 1893, p. 82. Type, by monotypy, *Coniornis altus* Marsh.

Coniornis altus Marsh

Coniornis altus Marsh, Amer. Journ. Sci., ser. 3, vol. 45, 1893, p. 82, text fig.

Upper Cretaceous (Judith River): Dog Creek, Montana.

---

[1] Type locality.

[2] Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, pp. 16, 75, considers this a synonym of *Hesperornis*.

Genus HARGERIA Lucas

Hargeria Lucas, Proc. U. S. Nat. Mus., vol. 26, Feb. 4, 1903, p. 552. Type, by orig. design., *Hesperornis gracilis* Marsh.

Hargeria gracilis (Marsh)

Hesperornis gracilis Marsh, Amer. Journ. Sci., ser. 3, vol. 11, 1876, p. 510.

Upper Cretaceous (Niobrara) : Near Smoky Hill River, western Kansas.

Family BAPTORNITHIDAE.[3] Baptornithes

Genus BAPTORNIS Marsh

Baptornis Marsh, Amer. Journ. Sci., ser. 3, vol. 14, 1877, p. 86. Type, by monotypy, *Baptornis advenus* Marsh.

Baptornis advenus Marsh

Baptornis advenus Marsh, Amer. Journ. Sci., ser. 3, vol. 14, 1877, p. 86.

Upper Cretaceous (Niobrara) : Wallace County,[4] and Butte Creek, Logan County, Kansas.

Order ICHTHYORNITHIFORMES. Ichthyornithes

Family ICHTHYORNITHIDAE. Ichthyornithes

Genus ICHTHYORNIS Marsh

Ichthyornis Marsh, Amer. Journ. Sci., ser. 3, vol. 4, November 1872, p. 344. Type, by monotypy, *Ichthyornis dispar* Marsh.

Ichthyornis agilis (Marsh)

Graculavus agilis Marsh, Amer. Journ. Sci., ser. 3, vol. 5, 1873, p. 230.

Upper Cretaceous (Niobrara) : Butte Creek, western Kansas.

Ichthyornis anceps (Marsh)

Graculavus anceps Marsh, Amer. Journ. Sci., ser. 3, vol. 3, 1872, p. 364.

Upper Cretaceous (Niobrara) : North Fork Smoky Hill River, about 12 miles east of Wallace, Kansas.

Ichthyornis dispar Marsh

Ichthyornis dispar Marsh, Amer. Journ. Sci., ser. 3, vol. 4, 1872, p. 344.

Upper Cretaceous (Niobrara) : Near Solomon River, Kansas.

---

[3] Lambrecht, Handb. Palaeorn., 1933, pp. 258-260, unites this with the Enaliornithidae, on what seem insufficient grounds. As suggested by Lucas, Proc. U. S. Nat. Mus., vol. 26, 1903, p. 555, *Baptornis* probably belongs in a distinct order.

[4] Type locality.

Ichthyornis lentus (MARSH)

  Graculavus lentus MARSH, Amer. Journ. Sci., ser. 3, vol. 14, 1877, p. 253.

  Upper Cretaceous: Near "Fort McKinney," Texas.

Ichthyornis tener MARSH

  Ichthyornis tener MARSH, Odontornithes, 1880, pp. 151, 198, pl. 30, fig. 8.

  Upper Cretaceous (Niobrara): Wallace County, Kansas.

Ichthyornis validus MARSH

  Ichthyornis validus MARSH, Odontornithes, 1880, pp. 147, 153, 198, pl. 30, figs. 11-14.

  Upper Cretaceous (Niobrara): Near Solomon River, Kansas.

Ichthyornis victor MARSH

  Ichthyornis victor MARSH, Amer. Journ. Sci., ser. 3, vol. 11, 1876, p. 511.

  Upper Cretaceous (Niobrara): Wallace County [5] and Hackberry Creek, near Smoky Hill River, Gove County, Kansas.

Family APATORNITHIDAE. APATORNITHES

Genus APATORNIS Marsh

  Apatornis MARSH, Amer. Journ. Sci., ser. 3, vol. 5, Jan. 21, 1873, p. 162. Type, by monotypy, *Ichthyornis celer* MARSH.

Apatornis celer (MARSH)

  Ichthyornis celer MARSH, Amer. Journ. Sci., ser. 3, vol. 5, 1873, p. 74.

  Upper Cretaceous (Niobrara): Butte Creek, near Smoky Hill River, Kansas.

Superorder PALAEOGNATHAE. STRUTHIOUS BIRDS AND ALLIES

Order CAENAGNATHIFORMES. CAENAGNATHUS

Family CAENAGNATHIDAE. CAENAGNATHUS

Genus CAENAGNATHUS Sternberg

  Caenagnathus STERNBERG, Journ. Pal., vol. 14, January 1940, p. 81. Type, by orig. design., *Caenagnathus collinsi* STERNBERG.

Caenagnathus collinsi STERNBERG [6]

  Caenagnathus collinsi STERNBERG, Journ. Pal., vol. 14, January 1940, p. 81, figs. 1-6.

  Upper Cretaceous (Pale beds, Belly River series): Quarry No. 112, Steveville map area, near mouth of Sand Creek, Alberta, Canada.

---

  [5] Type locality.

  [6] This interesting species, known from a nearly complete mandible, is listed in the above superorder tentatively. It is not absolutely certain that it is avian.

Superorder NEOGNATHAE. TYPICAL BIRDS

Order GAVIIFORMES. LOONS

Family GAVIIDAE. LOONS

Subfamily GAVIINAE

Genus GAVIA Forster

Gavia J. R. FORSTER, Enchirid. Hist. Nat., 1788, p. 38. Type, by subs. design., *Colymbus imber* GUNNERUS = *C. immer* BRÜNNICH (Allen, 1907).

Gavia concinna WETMORE

Gavia concinna WETMORE, Journ. Morph., vol. 66, Jan. 2, 1940, p. 25, figs. 1-4.

Lower Pliocene (Etchegoin beds): Sweetwater Canyon, $5\frac{1}{2}$ miles east of King City, Monterey County, California.

Subfamily GAVIELLINAE. GAVIELLA

Genus GAVIELLA Wetmore

Gaviella WETMORE, Journ. Morph., vol. 66, Jan. 2, 1940, p. 28. Type, by orig. design., *Gavia pusilla* SHUFELDT.

Gaviella pusilla (SHUFELDT)

Gavia pusilla SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 70, pl. 13, fig. 106.

Probably from Oligocene (White River beds): near Lusk, Wyoming.[7]

Order COLYMBIFORMES. GREBES

Family COLYMBIDAE. GREBES

Genus COLYMBUS Linnaeus

Colymbus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 135. Type, by subs. design., *Colymbus cristatus* LINNAEUS (Baird, Brewer, and Ridgway, 1884).

Subgenus COLYMBUS Linnaeus

Colymbus grisegena BODDAERT. Holboell's Grebe

Colymbus grisegena BODDAERT, Table Pl. Enl., 1783, p. 55.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

---

[7] See Wetmore, A., Journ. Morph., vol. 66, Jan. 2, 1940, p. 30.

Subgenus DYTES Kaup

Dytes KAUP, Skizz. Entw.-Gesch. Eur. Thierw., 1829, p. 41. Type, by subs. design., *Colymbus auritus* LINNAEUS (Gray, 1842).

Colymbus auritus LINNAEUS. Horned Grebe

Colymbus auritus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 135.

Modern form reported from Pleistocene: Cavern deposits of Tennessee; Seminole Field, Pinellas County, and Itchtucknee River, Florida; Fossil Lake, Oregon.

Colymbus nigricollis (BREHM). Eared Grebe

Podiceps nigricollis C. L. BREHM, Handb. Naturg. Vögel Deutschl., 1831, p. 963.

Modern form reported from Middle Pliocene (Edson beds): Sherman County, Kansas; and from Pleistocene: Fossil Lake, Oregon.

Colymbus oligoceanus SHUFELDT

Colymbus oligoceanus SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 54.

? Oligocene (John Day): Lower Willow Creek, Oregon.

Colymbus parvus SHUFELDT

Colymbus parvus SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 6, July 9, 1913, p. 136, pl. 39, fig. 477.

Pliocene: Kern County, California; Pleistocene: Fossil Lake, Oregon.[8]

Genus AECHMOPHORUS Coues

Æchmophorus COUES, Proc. Acad. Nat. Sci. Philadelphia, vol. 14, No. 5, April-May (Aug. 1), 1862, p. 229. Type, by orig. design., *Podiceps occidentalis* LAWRENCE.

Aechmophorus occidentalis (LAWRENCE). Western Grebe

Podiceps occidentalis LAWRENCE, in BAIRD, CASSIN, AND LAWRENCE, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, pp. liv, 892, 894.

Modern form reported from Pleistocene: Fossil Lake, Oregon; San Francisco Bay region (Rodeo); Upper San Pedro, near San Pedro, Playa del Rey, and Manix,[9] east of Barstow, California.

Aechmophorus lucasi MILLER

Aechmophorus lucasi L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 4, Feb. 4, 1911, p. 83, figs. 1-3.

Pleistocene: Fossil Lake, Oregon.

---

[8] Type locality.

[9] Possibly upper Pliocene according to Compton, L. V., Condor, 1934, p. 167.

Genus PODILYMBUS Lesson

Podilymbus LESSON, Traité d'Orn., livr. 8, June 11, 1831, p. 595. Type, by
monotypy, *Podiceps carolinensis* LATHAM = *Colymbus podiceps* LINNAEUS.

Podilymbus podiceps (LINNAEUS). Pied-billed Grebe

Colymbus Podiceps LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 136.

Modern form reported from Pleistocene: Seminole Field, Pinellas
County, and Itchtucknee River, Florida; Fossil Lake, Oregon;[10]
Rancho La Brea, Los Angeles, and McKittrick, California.

Order PROCELLARIIFORMES. ALBATROSSES, SHEARWATERS, PETRELS, AND ALLIES

Family DIOMEDEIDAE. ALBATROSSES

Genus DIOMEDEA Linnaeus

Diomedea LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 132. Type, by subs.
design., *Diomedea exulans* LINNAEUS (GRAY, 1840).

Diomedea albatrus PALLAS. Short-tailed Albatross

Diomedea albatrus PALLAS, Spic. Zool., vol. 1, fasc. 5, 1769, p. 28.

Modern form reported from Pleistocene (Upper San Pedro): near
Playa del Rey, California.

Family PROCELLARIIDAE. SHEARWATERS, FULMARS, AND PETRELS

Genus PUFFINUS Brisson [11]

Puffinus BRISSON, Orn., 1760, vol. 1, p. 56; vol. 6, p. 130. Type, by tautonymy,
Puffinus BRISSON = *Procellaria puffinus* BRÜNNICH.

Subgenus PUFFINUS Brisson

Puffinus griseus (GMELIN). Sooty Shearwater

Procellaria grisea GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 564.

Modern form reported from Pleistocene (Upper San Pedro): Near
San Pedro, and Playa del Rey, California.

---

[10] *Podilymbus magnus* SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, art.
6, July 9, 1913, p. 136, pl. 38, figs. 439-440, 449, has been identified as *P. podiceps*
by Wetmore, California Acad. Sci., vol. 23, Dec. 30, 1937, pp. 198-199.

[11] *Puffinus parvus* SHUFELDT, Ibis, October 1916, p. 632, from Recent deposits
in the bone caves of Bermuda is considered a synonym of *Puffinus lherminieri*.
Puffinus mcgalli SHUFELDT, Ibis, October 1916, p. 630, from Recent deposits
in the bone caves of Bermuda seemingly is *Puffinus puffinus*.

Puffinus puffinus (BRÜNNICH). **Manx Shearwater**

Procellaria Puffinus BRÜNNICH, Orn. Borealis, 1764, p. 29.

Modern form reported from Pleistocene: Melbourne, Florida.

Puffinus opisthomelas COUES. **Black-vented Shearwater**

Puffinus opisthomelas COUES, Proc. Acad. Nat. Sci. Philadelphia, vol. 16, No. 2, March-April (June 30), 1864, p. 139.

Modern form reported from Pleistocene (Upper San Pedro): San Pedro, and Playa del Rey, California.

Puffinus inceptor WETMORE

Puffinus inceptor WETMORE, Proc. California Acad. Sci., ser. 4, vol. 19, No. 8, July 15, 1930, p. 86, figs. 1-3.

Miocene (Temblor): Sharktooth Hill, about 7 miles northeast of Bakersfield, California.

Puffinus diatomicus MILLER

Puffinus diatomicus L. H. MILLER, Carnegie Inst. Washington, Publ. 349, August 1925, p. 111, pls. 1, 2, 7a.

Upper Middle Miocene (Temblor, *Turritella ocoyana* zone): Lompoc,[11a] and San Pedro Breakwater, San Pedro, California.

Subgenus ARDENNA Reichenbach

Ardenna REICHENBACH, Avium Syst. Nat., 1852 (1853), p. iv. Type, by monotypy, *Procellaria major* FABER = *P. gravis* O'REILLY.

Puffinus conradi MARSH

Puffinus conradi MARSH, Amer. Journ. Sci., ser. 2, vol. 49, 1870, p. 212.

Miocene (Calvert formation): Maryland.

Genus FULMARUS Stephens

Fulmarus "LEACH," STEPHENS, in SHAW, Gen. Zool., vol. 13, pt. 1, Feb. 18, 1826, p. 233. Type by subs. design., *Procellaria glacialis* LINNAEUS (Gray, 1855).

Fulmarus glacialis (LINNAEUS). **Fulmar**

Procellaria glacialis LINNAEUS, Fauna Suecica, 2d ed., 1761, p. 51.

Modern form reported from Pleistocene (Upper San Pedro): San Pedro, California.

[11a] Type locality.

Order PELECANIFORMES. Tropic-birds, Pelicans, Frigate-birds and Allies

Suborder PELECANI. Pelicans, Boobies, Cormorants, and Snake-birds

Superfamily PELECANOIDEA. Pelicans and Allies

Family PELECANIDAE. Pelicans

Genus PELECANUS Linnaeus

Pelecanus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 132. Type, by subs. design., *Pelecanus onocrotalus* Linnaeus (Gray, 1840).

Subgenus CYRTOPELICANUS Reichenbach

Cyrtopelicanus Reichenbach, Avium Syst. Nat., 1852 (1853), p. vii. Type, by orig. design., *Pelecanus trachyrhynchus* Latham = *P. erythrorhynchos* Gmelin.

Pelecanus erythrorhynchos Gmelin. White Pelican

Pelecanus erythrorhynchos Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 571.

Modern form reported from Pleistocene: Fossil Lake, Oregon; Manix,[12] east of Barstow, San Bernardino County, California; ? Pleistocene: Rattlesnake Hill, Fallon, Nevada.

Pelecanus halieus Wetmore

Pelecanus halieus Wetmore, Smithsonian Misc. Coll., vol. 87, No. 20, Dec. 27, 1933, p. 3, figs. 1-2.

Upper Pliocene (Hagerman Lake beds) : Near Hagerman, Idaho.

Family CYPHORNITHIDAE. Cyphornithes

Genus CYPHORNIS Cope

Cyphornis Cope, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 9, sign. 58, May 31, 1894, p. 449. Type, by monotypy, *Cyphornis magnus* Cope.

Cyphornis magnus Cope

Cyphornis magnus Cope, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 9, sig. 58, May 31, 1894, p. 451.

Miocene? : Carmanah Point, Vancouver Island.

---

[12] Possibly upper Pliocene according to Compton, L. V., Condor, 1934, p. 167.

Genus PALAEOCHENÖIDES Shufeldt

Palaeochenöides Shufeldt, Geol. Mag., n. s., 4, vol. 3, August 1916, p. 347. Type, by monotypy, *Palaeochenöides mioceanus* Shufeldt.

Palaeochenöides mioceanus Shufeldt

Palaeochenöides mioceanus Shufeldt, Geol. Mag., n. s., 4, vol. 3, August 1916, p. 347, pl. 15.

Miocene: Near source of Stono River, South Carolina.

Superfamily SULOIDEA. Boobies, Cormorants, and Allies

Family SULIDAE. Boobies and Gannets

Genus SULA Brisson

Sula Brisson, Orn., 1760, vol. 1, p. 60; vol. 6, p. 494. Type, by tautonymy, *Sula* Brisson = *Pelecanus piscator* Linnaeus.

Subgenus SULA Brisson

Sula stocktoni Miller

Sula stocktoni L. H. Miller, Publ. Univ. California at Los Angeles Biol. Sci., vol. 1, No. 5, Mar. 12, 1935, p. 75, fig. 2.

Upper Middle Miocene (Temblor phase of Monterey): Near Lomita, California.

Sula willetti Miller

Sula willetti L. H. Miller, Carnegie Inst. Washington, Publ. 349, August 1925, p. 112, pls. 3, 8, fig. 1.

Miocene (Temblor, *Turritella ocoyana* zone): Lompoc, California.

Subgenus MICROSULA Wetmore

Microsula Wetmore, Proc. U. S. Nat. Mus., vol. 85, Jan. 14, 1938, p. 25. Type, by orig. design., *Sula (Microsula) avita* Wetmore.

Sula avita Wetmore

Sula avita Wetmore, Proc. U. S. Nat. Mus., vol. 85, Jan. 14, 1938, p. 22, figs. 2-3.

Miocene (Calvert formation): Chesapeake Bay near Plumpoint, Maryland.

Genus MIOSULA Miller

Miosula L. H. Miller, Carnegie Inst. Washington, Publ. 349, August 1925, p. 114. Type, by monotypy, *Miosula media* Miller.

Miosula media Miller

Miosula media L. H. Miller, Carnegie Inst. Washington, Publ. 349, August 1925, p. 114, pl. 5.

Miocene (Temblor, *Turritella ocoyana* zone): Lompoc, California.

Genus MORIS Leach

Moris LEACH, Syst. Cat. Spec. Indig. Mamm. and Birds Brit. Mus., 1816, (after Aug.), p. 35. Type, by monotypy, *Moris bassana* LEACH = *Pelecanus bassanus* LINNAEUS.

Moris loxostyla (COPE)[13]

Sula loxostyla COPE, Trans. Amer. Phil. Soc., n. s., vol. 14, December 1870, p. 236, fig. 53.

Miocene: Calvert County, Maryland; New Jersey.

Moris vagabundus WETMORE

Moris vagabundus WETMORE, Proc. California Acad. Sci., ser. 4, vol. 19, No. 8, July 15, 1930, p. 89, fig. 4.

Miocene (Temblor): Sharktooth Hill,[14] about 7 miles northeast, and west branch of Granite Creek 11 miles north, of Bakersfield, California.

Moris lompocana (MILLER)

Sula lompocana L. H. MILLER, Carnegie Inst. Washington, Publ. 349, August 1925, p. 114, pls. 4, 7b, 9.

Miocene (Temblor, *Turritella ocoyana* zone): Lompoc, California.

Moris reyana HOWARD

Moris reyana HOWARD, Condor, vol. 38, September 15, 1936, p. 213, fig. 37.
Pleistocene (Upper San Pedro): Near Playa del Rey, California.

Family PHALACROCORACIDAE. CORMORANTS

Genus GRACULAVUS Marsh[15]

Graculavus MARSH, Amer. Journ. Sci., ser. 3, vol. 3, 1872, p. 363. Type, by subs. design., *Graculavus velox* MARSH (Hay, 1902).

Graculavus pumilus MARSH

Graculavus pumilus MARSH, Amer. Journ. Sci., ser. 3, vol. 3, 1872, p. 364.

Eocene (Hornerstown): Hornerstown, New Jersey.

Graculavus velox MARSH

Graculavus velox MARSH, Amer. Journ. Sci., ser. 3, vol. 3, 1872, p. 363.

Eocene (Hornerstown): Hornerstown, New Jersey.

---

[13] *Sula atlantica* SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 62, pl. 15, fig. 123, from the Miocene of New Jersey, is considered a synonym of *M. loxostyla* (cf. WETMORE, Auk, 1926, p. 465).

[14] Type locality.

[15] *Limosavis* SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 19, proposed as a new genus for *Graculavus velox* MARSH, is a synonym of *Graculavus* MARSH.

Genus **PHALACROCORAX** Brisson [16]

Phalacrocorax Brisson, Orn., 1760, vol. 1, p. 60; vol. 6, p. 511. Type, by tautonymy, *Phalacrocorax* Brisson = *Pelecanus carbo* Linnaeus.

Phalacrocorax auritus (Lesson). **Double-crested Cormorant**

Carbo auritus Lesson, Traité d'Orn., livr. 8, June 11, 1831, p. 605.

Modern form reported from Upper Pliocene (Hagerman Lake beds) : Near Hagerman, Idaho; Pleistocene: Melbourne (Stratum 2), Sarasota, Seminole Field, Pinellas County, Itchtucknee River and Vero, Florida; Santa Monica, California; ? Pleistocene: Rattlesnake Hill, Fallon, Nevada.

Phalacrocorax femoralis Miller

Phalacrocorax femoralis L. H. Miller, Condor, vol. 31, No. 4, July 15, 1929, p. 167, figs. 58-59.

Late Miocene or early Pliocene (Modelo formation) : Calabasas, California.

Phalacrocorax idahensis (Marsh)

Graculus idahensis Marsh, Amer. Journ. Sci., ser. 2, vol. 49, 1870, p. 216.

Pliocene: Castle Creek, Owyhee County, and near Hagerman (upper Pliocene of Hagerman lake beds), Idaho.

Phalacrocorax macropus (Cópe)

Graculus macropus Cope, Bull. Geol. and Geogr. Surv. Terr., vol. 4, No. 2, 1878, p. 386.

Lower Miocene (base of Arikaree) : North side of Cottonwood Creek, southeastern Montana; [17] Pleistocene: Fossil Lake, Oregon.

Phalacrocorax marinavis Shufeldt

Phalacrocorax marinavis Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 56, pl. 14, figs. 114, 116-118, 122.

? Oligocene (John Day) : Willow Creek, Oregon.

Phalacrocorax mediterraneus Shufeldt

Phalacrocorax mediterraneus Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 58, pl. 15, fig. 138.

Middle Oligocene (White River) : Gerry's Ranch, Northern Colorado.

---

[16] Further study is required before the fossil cormorants listed here can be assigned to subgenera.

[17] Shufeldt, Auk, 1915, pp. 485-488, has identified material from the Miocene of Montana as of this species. The type locality is in the Pleistocene.

Phalacrocorax rogersi HOWARD

 Phalacrocorax rogersi HOWARD, Condor, vol. 34, No. 3, May 16, 1932, p. 118,
  fig. 19.

Pliocene: Veronica Springs Stone Quarry, near Santa Barbara,
California.

Family ANHINGIDAE. SNAKE-BIRDS

Genus ANHINGA Brisson

 Anhinga BRISSON, Orn., 1760, vol. 1, p. 60; vol. 6, p. 476. Type, by monotypy,
  Anhinga BRISSON = *Plotus anhinga* LINNAEUS.

Anhinga anhinga (LINNAEUS). **Water-turkey**

 Plotus Anhinga LINNAEUS, Syst. Nat., 12th ed., vol. 1, 1766, p. 218.

Modern form reported from Pleistocene: Melbourne (Stratum 2),
Florida.

Order CICONIIFORMES. HERONS, STORKS, AND ALLIES

Suborder ARDEAE. HERONS, BITTERNS, AND ALLIES

Family ARDEIDAE. HERONS AND BITTERNS

Subfamily ARDEINAE. HERONS AND EGRETS

Genus ARDEA Linnaeus [18]

 Ardea LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 141. Type, by subs.
  design., *Ardea cinerea* LINNAEUS (Gray, 1840).

Ardea herodias LINNAEUS. **Great Blue Heron**

 Ardea Herodias LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 143.

Modern form reported from Pleistocene: Vero (Stratum 3), Mel-
bourne, Itchtucknee River, Bradenton and Seminole Field, Pinellas
County, Florida; Fossil Lake, Oregon; Rancho La Brea, Los Angeles,
and McKittrick, California.

Ardea paloccidentalis SHUFELDT

 Ardea paloccidentalis SHUFELDT, Amer. Nat., vol. 25, No. 297, September
  1891, p. 820.

Pleistocene: Fossil Lake, Oregon.

---

 [18] *Ardea sellardsi* SHUFELDT, Journ. Geol., January-February (January) 1917,
p. 19, described from Vero (Stratum 3), Florida, proves to be based on the
tibiotarsus of *Meleagris gallopavo*. See Wetmore, Smithsonian Misc. Coll., vol.
85, No. 2, Apr. 13, 1931, p. 32.

Genus CASMERODIUS Gloger

Casmerodius GLOGER, Hand- und Hilfsbuch Naturg., 1842 (pp. 1-450, 1841), p. 412. Type, by subs. design., *Ardea egretta* GMELIN (Salvadori, 1882).

Casmerodius albus (GMELIN). American Egret

Ardea egretta GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 629.

Modern form reported from Pleistocene: Melbourne, Seminole Field, Pinellas County, and Venice, Florida; Rancho La Brea, Los Angeles, California.

Genus EGRETTA Forster

Egretta T. FORSTER, Syn. Cat. Brit. Birds, 1817, p. 59. Type, by monotypy, *Ardea garzetta* LINNAEUS.

Egretta thula (MOLINA). Snowy Egret

Ardea Thula MOLINA, Sagg. Stor. Nat. Chili, 1782, p. 235.

Modern form reported from Pleistocene: Bradenton, Florida.

Genus HYDRANASSA Baird

Hydranassa BAIRD, in BAIRD, CASSIN, AND LAWRENCE, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, p. 660. Type, by orig. design., *Ardea ludoviciana* WILSON = *Egretta ruficollis* GOSSE.

Hydranassa tricolor (MÜLLER). Louisiana Heron

Ardea tricolor MÜLLER, Natursyst. Suppl., 1776, p. 111.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Genus FLORIDA Baird

Florida BAIRD, in BAIRD, CASSIN, AND LAWRENCE, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, pp. xxi, xlv, 659, 671. Type, by monotypy, *Ardea caerulea* LINNAEUS.

Florida caerulea (LINNAEUS). Little Blue Heron

Ardea caerulea LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 143.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Genus BUTORIDES Blyth

Butorides BLYTH, Cat. Birds Mus. Asiatic Soc., 1849 (1852?), p. 281. Type, by monotypy, *Ardea javanica* HORSFIELD.

Butorides virescens (LINNAEUS). Green Heron

Ardea virescens LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 144.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida; Rancho La Brea, Los Angeles, California.

Genus NYCTICORAX Forster

Nycticorax T. FORSTER, Syn. Cat. Brit. Birds, 1817, p. 59. Type, by mono-
typy, *Nycticorax infaustus* FORSTER = *Ardea nycticorax* LINNAEUS.

Nycticorax nycticorax (LINNAEUS). Black-crowned Night Heron

Ardea nycticorax LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 142.

Modern form reported from Pleistocene: Bradenton, and Itchtuck-
nee River, Florida; McKittrick, and Rancho La Brea, Los Angeles,
California.

Genus NYCTANASSA Stejneger

Nyctanassa STEJNEGER, Proc. U. S. Nat. Mus., vol. 10, Aug. 3, 1887, p. 295,
note. Type, by orig. design., *Ardea violacea* LINNAEUS.

Nyctanassa violacea (LINNAEUS). Yellow-crowned Night Heron [19]

Ardea violacea LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 143.

Modern form reported from Pleistocene: Seminole Field, Pinellas
County, and Vero, Florida.

Genus EOCEORNIS Shufeldt

Eoceornis SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February
1915, p. 39. Type, by monotypy, *Eoceornis ardetta* SHUFELDT.

Eoceornis ardetta SHUFELDT

Eoceornis ardetta SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19,
February 1915, p. 39, pl. 13, fig. 102.

Eocene (Bridger): Henry's Fork, Wyoming.

Subfamily BOTAURINAE. BITTERNS

Genus BOTAURUS Stephens

Botaurus STEPHENS, in SHAW, Gen. Zool., vol. 11, pt. 2, August 1819, p.
592. Type, by subs. design., *Ardea stellaris* LINNAEUS (Gray, 1840).

Botaurus lentiginosus (MONTAGU). American Bittern

Ardea lentiginosa MONTAGU, Suppl. Orn. Dict., 1813, not paged, see under
Heron, Freckled.

Modern form reported from Pleistocene: Seminole Field, Pinellas
County, and Sarasota, Florida; Fossil Lake, Oregon; Rancho La Brea,
Los Angeles, California.

---

[19] *Larus vero* SHUFELDT, Journ. Geol., 1917, p. 18, from Pleistocene of Vero,
Florida, is *Nyctanassa violacea*, according to Wetmore, Smithsonian Misc. Coll.,
vol. 85, No. 2, 1931, pp. 3, 11, and 16.

Genus BOTAUROIDES Shufeldt

Botauroides SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 33. Type, by monotypy, *Botauroides parvus* SHUFELDT.

Botauroides parvus SHUFELDT

Botauroides parvus SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 33.

Eocene (? Bridger): "Spanish John Meadow," Wyoming.

Suborder CICONIAE. STORKS, IBISES, AND SPOONBILLS

Superfamily CICONIOIDEA. STORKS

Family CICONIIDAE. STORKS AND JABIRUS

Subfamily CICONIINAE. STORKS

Genus JABIRU Hellmayr [20]

Jabiru HELLMAYR, Abh. Kön. Bayer. Akad. Wiss., II Kl., vol. 22, May 1906, p. 711. Type, by orig. design., *Ciconia mycteria* LICHTENSTEIN.

Jabiru mycteria (LICHTENSTEIN). Jabiru

Ciconia mycteria LICHTENSTEIN, Abh. Kön. Akad. Wiss. Berlin, Phys. Kl., for 1816-1817 (1819), p. 163.

Modern form reported from Pleistocene: Vero (Stratum 2), Melbourne (Stratum 2), Itchtucknee River, Seminole Field, Pinellas County and Venice, Florida.

Genus CICONIA Brisson

Ciconia BRISSON, Orn., 1760, vol. 1, p. 48; vol. 5, p. 361. Type, by tautonymy, *Ciconia alba = Ardea ciconia* LINNAEUS.

Ciconia maltha MILLER

Ciconia maltha L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 5, No. 30, Aug. 5, 1910, p. 440, figs. 1-7.

Pleistocene: Carpinteria, McKittrick, and Rancho La Brea,[20a] Los Angeles, California.

---

[20] *Jabiru weillsi* Sellards, Florida State Geol. Surv., 8th Ann. Rep., 1916, p. 14, pl. 26, figs. 1-4, text-fig. 15, fig. C, is a synonym of *Jabiru mycteria* (Lichtenstein). See Wetmore, Smithsonian Misc. Coll., vol. 85, No. 2, Apr. 13, 1931, p. 17.

[20a] Type locality.

Subfamily MYCTERIINAE. Wood Ibises

Genus MYCTERIA Linnaeus

Mycteria Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 140. Type, by monotypy, *Mycteria americana* Linnaeus.

Mycteria wetmorei Howard [21]

Mycteria wetmorei Howard, Condor, vol. 37, Sept. 15, 1935, p. 253, fig. 47.

Pleistocene: Rancho La Brea, Los Angeles, California.

Superfamily THRESKIORNITHOIDEA. Ibises and Spoonbills

Family THRESKIORNITHIDAE. Ibises and Spoonbills

Subfamily THRESKIORNITHINAE. Ibises

Genus PLEGADIS Kaup

Plegadis Kaup, Skizz. Entw.-Ges. Eur. Thierw., 1829, p. 82. Type, by monotypy, *Tantalus falcinellus* Linnaeus.

Plegadis guarauna (Linnaeus). **White-faced Glossy Ibis**

Scolopax Guarauna Linnaeus, Syst. Nat., 12th ed., vol. 1, 1766, p. 242.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Genus GUARA Reichenbach

Guara Reichenbach, Avium Syst. Nat., 1852 (1853), p. xiv. Type, by orig. design., *Scolopax rubra* Linnaeus.

Guara alba (Linnaeus). **White Ibis**

Scolopax alba Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 145.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Subfamily PLATALEINAE. Spoonbills

Genus AJAIA Reichenbach

Ajaia Reichenbach, Avium Syst. Nat., 1852 (1853), p. xvi. Type, by orig. design., *Ajaia rosea* Reichenbach = *Platalea ajaja* Linnaeus.

Ajaia ajaja (Linnaeus). **Roseate Spoonbill**

Platalea ajaja Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 140.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

---

[21] Replaces *Mycteria americana* as listed in Check-list of North American Birds, 4th ed., 1931, p. 416.

Suborder PHOENICOPTERI. Flamingos

Family PHOENICOPTERIDAE. Flamingos

Genus PHOENICOPTERUS Linnaeus

Phoenicopterus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 139. Type, by monotypy, *Phoenicopterus ruber* Linnaeus.

Phoenicopterus copei Shufeldt

Phoenicopterus copei Shufeldt, Amer. Nat., vol. 25, No. 297, September 1891, p. 820.

Pleistocene: Fossil Lake, Oregon.

Order ANSERIFORMES. Screamers, Swans, Geese, and Ducks

Suborder ANSERES. Swans, Geese, Ducks, and Allies

Family PARANYROCIDAE. Paranyroca

Genus PARANYROCA Miller and Compton

Paranyroca A. H. Miller and L. V. Compton, Condor, vol. 41, July 15, 1939, p. 153. Type, by orig. design., *Paranyroca magna* Miller and Compton.

Paranyroca magna Miller and Compton

Paranyroca magna A. H. Miller and L. V. Compton, Condor, vol. 41, July 15, 1939, p. 153, fig. 34 A, C, D, E.

Lower Miocene (Rosebud formation): Flint Hill, 9 miles west-southwest of Martin, Bennett County, South Dakota.

Family ANATIDAE. Swans, Geese, and Ducks

Subfamily CYGNINAE. Swans

Genus CYGNUS Bechstein

Cygnus Bechstein, Orn. Taschenb. Deutschl., vol. 2, 1803, p. 404, footnote. Type, by tautonymy, *Anas cygnus* Linnaeus.

Subgenus CYGNUS Bechstein

Cygnus columbianus (Ord). Whistling Swan

Anas columbianus Ord, in Guthrie, Geogr., 2d Amer. ed., 1815, p. 319.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida; Fossil Lake, Oregon; Rancho La Brea, Los Angeles, and McKittrick, California.

Subgenus CLANGOCYCNUS Oberholser

Clangocycnus OBERHOLSER, Emu, vol. 8, pt. 1, July 1908, p. 3. Type, by
monotypy, *Cygnus buccinator* RICHARDSON.

Cygnus buccinator RICHARDSON.   Trumpeter Swan

Cygnus buccinator RICHARDSON, in WILSON AND BONAPARTE, Amer. Orn.,
Jameson ed., vol. 4, August 1831, p. 345.

Modern form reported from Pleistocene: Aurora, Illinois; Itchtuck-
nee River, Florida; Fossil Lake, Oregon.

Cygnus matthewi (SHUFELDT)[22]

Olor matthewi SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, July 9,
1913, p. 151, pl. 26, fig. 309, pl. 35, fig. 422.

Pleistocene: Fossil Lake, Oregon.

Cygnus paloregonus COPE[22]

Cygnus paloregonus COPE, Bull. Geol. and Geogr. Surv. Terr., vol. 4, No. 2,
1878, p. 388.

Pleistocene: Fossil Lake, Oregon;[23] Froman's Ferry, Idaho.

Subfamily ANSERINAE. GEESE

Genus BRANTA Scopoli

Branta SCOPOLI, Annus 1, Historico-Naturalis, 1769, p. 67. Type, by tau-
tonymy, *Anas bernicla* LINNAEUS (*Branta* ALDROVANDUS, in synonymy).

Branta canadensis (LINNAEUS).   Canada Goose

Anas canadensis LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 123.

Modern form reported from Pleistocene: Seminole Field, Pinellas
County, and Itchtucknee River, Florida; Fossil Lake, Oregon; Potter
Creek Cave, Shasta County, Alameda County, Rancho La Brea, Los
Angeles, and Upper San Pedro formation, San Pedro, California.
? Pleistocene: Rattlesnake Hill, Fallon, Nevada.[24]

Branta canadensis hutchinsi (RICHARDSON).   Hutchins's Goose

Anser Hutchinsii RICHARDSON, in SWAINSON AND RICHARDSON, Fauna Bor.-
Amer., vol. 2, 1831 (1832), p. 470.

Modern form reported from Pleistocene: Seminole Field, Pinellas
County, Itchtucknee River, and Melbourne, Florida.

---

[22] Subgeneric allocation doubtful.

[23] Type locality.

[24] Recorded as *Branta canadensis canadensis*.

Branta esmeralda BURT

Branta esmeralda BURT, Univ. California Publ., Bull. Dep. Geol. Sci., vol. 18, No. 6, Mar. 19, 1929, p. 222, pl. 20.

Lower Pliocene (Esmeralda beds [25]) : Fish Lake Valley, Esmeralda County, Nevada.

Branta howardae MILLER

Branta howardae L. H. MILLER, Condor, vol. 32, No. 4, July 15, 1930, p. 208, fig. 74.

Lower Pliocene (Ricardo formation) : Mojave Desert area, California.

Branta bernicla (LINNAEUS). **Brant**

Anas bernicla LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 124.

Modern form reported from Pleistocene : Fossil Lake, Oregon.

Branta dickeyi MILLER

Branta dickeyi L. H. MILLER, Condor, vol. 26, No. 5, Sept. 15, 1924, p. 179, fig. 46.

Pleistocene : McKittrick, California.

Branta hypsibata (COPE)

Anser hypsibatus COPE, Bull. Geol. and Geogr. Surv. Terr., vol. 4, No. 2, 1878, p. 387.

Pleistocene : Fossil Lake, Oregon.

Branta propinqua SHUFELDT

Branta propinqua SHUFELDT, Journ. Acad. Nat. Sci. Philadelphia, 2d ser., vol. 9, sign. 53, Oct. 20, 1892, p. 407, pl. 15, fig. 17.

Pleistocene : Fossil Lake, Oregon.

Genus ANABERNICULA Ross

Anabernicula Ross, Trans. San Diego Soc. Nat. Hist., vol. 8, No. 15, Aug. 24, 1935, p. 107. Type, by monotypy, *Anabernicula gracilenta* Ross = *Branta minuscula* WETMORE.[26]

Anabernicula minuscula (WETMORE)

Branta minuscula WETMORE, Proc. U. S. Nat. Mus., vol. 64, art. 5, Jan. 15, 1924, p. 6, figs. 3-4.

Upper Pliocene : Near Benson, Arizona ; [27] Pleistocene : McKittrick and Rancho La Brea, Los Angeles, California.

---

[25] Possibly Upper Miocene.

[26] See Howard, H., Condor, 1936, p. 35.

[27] Type locality.

Genus PRESBYCHEN Wetmore

Presbychen WETMORE, Proc. California Acad. Sci., ser. 4, vol. 19, No. 8, July 15, 1930, p. 92. Type, by orig. design., *Presbychen abavus* WETMORE.

Presbychen abavus WETMORE

Presbychen abavus WETMORE, Proc. California Acad. Sci., ser. 4, vol. 19, No. 8, July 15, 1930, p. 92, figs. 5-7.

Miocene (Temblor) : Sharktooth Hill, Kern County, about 7 miles northeast of Bakersfield, California.

Genus ANSER Brisson

Anser BRISSON, Orn., 1760, vol. 1, p. 58; vol. 6, p. 261. Type, by tautonymy, *Anser domestica* BRISSON = *Anas anser* LINNAEUS.

Anser albifrons (SCOPOLI). White-fronted Goose

Branta albifrons SCOPOLI, Annus 1, Historico-Naturalis, 1769, p. 69.

Modern form reported from Pleistocene: Fossil Lake, Oregon; Upper San Pedro formation, San Pedro, and Rancho La Brea, Los Angeles, California.

Anser condoni SHUFELDT

Anser condoni SHUFELDT, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 9, sign. 53, Oct. 20, 1892, p. 406, pl. 16, figs. 19, 26, 27.

Pleistocene: Fossil Lake, Oregon.

Genus CHEN Boie

Chen BOIE, Isis von OKEN (vol. 10), heft 5 (May), 1822, col. 563. Type, by monotypy, *Anser hyperboreus* PALLAS.

Subgenus CHEN Boie

Chen hyperborea (PALLAS). Snow Goose

Anser hyperboreus PALLAS, Spic. Zool., vol. 1, fasc. 6, 1769, p. 25.

Modern form reported from Pleistocene: Fossil Lake, Oregon; Rancho La Brea, Los Angeles, and McKittrick, California.

Chen caerulescens (LINNAEUS). Blue Goose

Anas cærulescens LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 124.

Modern form reported from Pleistocene: Fossil Lake, Oregon.[28]

---

[28] Recorded by Shufeldt, Bull. Amer. Mus. Nat. Hist., vol. 32, July 9, 1913, p. 145, on basis of scapula only.

Chen pressa WETMORE [29]

> *Chen pressa* WETMORE, Smithsonian Misc. Coll., vol. 87, No. 20, Dec. 27, 1933,
>   p. 9, figs. 5-8.

Upper Pliocene (Hagerman Lake Beds) : Near Hagerman, Idaho.

Subfamily DENDROCYGNINAE. TREE-DUCKS

Genus DENDROCYGNA Swainson

Dendrocygna SWAINSON, Class. Birds, vol. 2 (July 1), 1837, p. 365. Type,
    by subs. design., *Anas arcuata* HORSFIELD (Gray, 1840).

Dendrocygna eversa WETMORE

> *Dendrocygna eversa* WETMORE, Proc. U. S. Nat. Mus., vol. 64, art. 5, Jan.
>   15, 1924, p. 3, figs. 1-2.

Upper Pliocene : Near Benson, Arizona.

Subfamily ANATINAE. SURFACE-FEEDING DUCKS

Genus ANAS Linnaeus

Anas LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 122. Type, by subs.
    design., *Anas boschas* LINNAEUS = *A. platyrhynchos* LINNAEUS (Lesson,
    1828).

Anas platyrhynchos LINNAEUS. **Mallard**

> *Anas platyrhynchos* LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 125.

Modern form reported from Pleistocene : Fossil Lake, Oregon;
Rancho La Brea, Los Angeles, McKittrick, Carpinteria, and Upper
San Pedro formation, San Pedro, California; Itchtucknee River,
Florida.

Anas rubripes BREWSTER. **Black Duck**

> *Anas obscura rubripes* BREWSTER, Auk, vol. 19, No. 2, April 1902, p. 184.

Modern form reported from Pleistocene : Itchtucknee River,
Florida.

Anas fulvigula RIDGWAY. **Florida Duck**

> *Anas obscura* var. *fulvigula* RIDGWAY, Amer. Nat., vol. 8, No. 2, February
>   1874, p. 111.

Modern form reported from Pleistocene : Seminole Field, Pinellas
County, Itchtucknee River, and Bradenton, Florida.

---

[29] Miller, A. H., Univ. California Publ. Zool., vol. 42, No. 1, 1937, p. 41,
suggests that this species may belong in the genus *Nesochen*.

Genus CHAULELASMUS Bonaparte

Chaulelasmus "G. R. GRAY" BONAPARTE, Geogr. and Comp. List, 1838, p. 56. Type, by monotypy, *Anas strepera* LINNAEUS.

Chaulelasmus streperus (LINNAEUS). Gadwall

Anas strepera LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 125.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, Los Angeles, California.[30]

Genus MARECA Stephens

Mareca STEPHENS, in SHAW, Gen. Zool., vol. 12, pt. 2, 1824, p. 130. Type, by subs. design., *Mareca fistularis* STEPHENS = *Anas penelope* LINNAEUS (Eyton, 1838).

Mareca americana (GMELIN). Baldpate

Anas americana GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 526.

Modern form reported from Pleistocene: Fossil Lake, Oregon; McKittrick, California.

Genus DAFILA Stephens

Dafila STEPHENS, in SHAW, Gen. Zool., vol. 12, pt. 2, 1824, p. 126. Type, by monotypy, *Dafila caudacuta* STEPHENS = *Anas acuta* LINNAEUS.

Dafila acuta (LINNAEUS). Pintail

Anas acuta LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 126.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Genus NETTION Kaup

Nettion KAUP, Skizz. Entw.-Ges. Eur. Thierw., 1829, p. 95. Type, by monotypy, *Anas crecca* LINNAEUS.

Nettion carolinense (GMELIN). Green-winged Teal

Anas carolinensis GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 533.

Modern form reported from Lower Pliocene: Cedar Mountain, Nevada; Hemphill County, Texas; Pleistocene: Seminole Field, Pinellas County, Florida; Fossil Lake, Oregon; Hawver Cave, Eldorado County, Rancho La Brea, Los Angeles, McKittrick, and Upper San Pedro formation, San Pedro, California.

---

[30] Listed erroneously in Check-list of North American Birds, 4th ed., 1931, p. 421, from Itchtucknee River, Florida.

Genus QUERQUEDULA Stephens

Querquedula STEPHENS, in SHAW, Gen. Zool., vol. 12, pt. 2, 1824, p. 142. Type, by tautonymy, *Anas circia* LINNAEUS = *Anas querquedula* LINNAEUS.

Querquedula discors (LINNAEUS). Blue-winged Teal

Anas discors LINNAEUS, Syst. Nat., 12th ed., vol. 1, 1766, p. 205.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Querquedula cyanoptera (VIEILLOT). Cinnamon Teal

Anas cyanoptera VIEILLOT, Nouv. Dict. d'Hist. Nat., nouv. éd., vol. 5, 1816, p. 104.

Modern form reported from Pleistocene: McKittrick, and Upper San Pedro formation, San Pedro, California.[31]

Querquedula floridana SHUFELDT

Querquedula floridana SHUFELDT, 9th Ann. Rep. Florida State Geol. Surv., 1917, p. 36, pl. 1, fig. 4, pl. 2, fig. 25.

Pleistocene: Vero [32] (Stratum 2), Melbourne, Seminole Field, Pinellas County, Venice, and Itchtucknee River, Florida.

Genus SPATULA Boie

Spatula BOIE, Isis von OKEN, vol. 10, heft 5, May 1822, col. 564. Type, by monotypy, *Anas clypeata* LINNAEUS.

Spatula clypeata (LINNAEUS). Shoveller

Anas clypeata LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 124.

Modern form reported from Pleistocene: Fossil Lake, Oregon; McKittrick, California.

Genus AIX Boie

Aix BOIE, Isis von OKEN, vol. 21, heft 3-4, March-April 1828, col. 329. Type, by subs. design., *Anas sponsa* LINNAEUS (Eyton, 1838).

Aix sponsa (LINNAEUS). Wood Duck

Anas Sponsa LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 128.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Subfamily NYROCINAE. DIVING DUCKS

Genus NYROCA Fleming

Nyroca FLEMING, Phil. Zool., vol. 2, 1822, p. 260. Type, by tautonymy, *Anas nyroca* GÜLDENSTÄDT.

---

[31] Record from Fossil Lake, Oregon, by Shufeldt, is only tentative.
[32] Type locality.

Subgenus NYROCA Fleming

Nyroca americana (EYTON). **Redhead**

Fuligula americana EYTON, Monogr. Anatidæ, 1838, p. 155.

Modern form reported from Pleistocene: McKittrick, California.

Nyroca collaris (DONOVAN). **Ring-necked Duck**

Anas collaris DONOVAN, Brit. Birds, vol. 6, 1809, pl. 147.

Modern form reported from Lower Pliocene: Cedar Mountain, Nevada.

Subgenus ARISTONETTA Baird

Aristonetta BAIRD, in BAIRD, CASSIN, AND LAWRENCE, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, p. 793. Type, by orig. design., *Anas valisineria* WILSON.

Nyroca valisineria (WILSON). **Canvasback**

Anas valisineria WILSON, Amer. Orn., vol. 8, 1814, p. 103, pl. 70, fig. 5.

Modern form reported from Pleistocene: Itchtucknee River, Florida; Fossil Lake, Oregon.

Subgenus FULIX Sundevall

Fulix SUNDEVALL, Kongl. Vetensk. Akad. Handl., 1835 (1836), p. 129. Type, by subs. design., *Anas marila* LINNAEUS (Baird, Brewer, and Ridgway, 1884).

Nyroca affinis (EYTON). **Lesser Scaup Duck**

Fuligula affinis EYTON, Monogr. Anatidae, 1838, p. 157.

Modern form reported from Pleistocene: Melbourne (Stratum 2), Itchtucknee River, Seminole Field, Pinellas County, Venice, and cave deposits near Lecanto, Florida.

Genus GLAUCIONETTA Stejneger

Glaucionetta STEJNEGER, Proc. U. S. Nat. Mus., vol. 8, Oct. 3, 1885, p. 409. Type, by orig. design., *Anas clangula* LINNAEUS.

Glaucionetta islandica (GMELIN). **Barrow's Golden-eye**

Anas islandica GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 541.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Genus CHARITONETTA Stejneger

Charitonetta STEJNEGER, Bull. U. S. Nat. Mus., No. 29, 1885, p. 163. Type, by orig. design., *Anas albeola* LINNAEUS.

Charitonetta albeola (LINNAEUS). **Buffle-head**

Anas Albeola LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 124.

Modern form reported from Pleistocene: Fossil Lake, Oregon; McKittrick, California.

Genus CLANGULA Leach

Clangula LEACH, in Ross, Voyage Discovery, 1819, app., p. xlviii. Type, by monotypy, *Clangula glacialis = Anas hyemalis* LINNAEUS.

Clangula hyemalis (LINNAEUS). Old-squaw

Anas hyemalis LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 126.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Genus HISTRIONICUS Lesson

Histrionicus LESSON, Man. d'Orn., vol. 2, 1828, p. 415. Type, by orig. design., *Anas histrionica* LINNAEUS.

Histrionicus histrionicus (LINNAEUS). Harlequin Duck

Anas histrionica LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 127.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Genus POLYSTICTA Eyton

Polysticta EYTON, Cat. Brit. Birds, 1836, p. 58. Type, by monotypy, *Anas stelleri* PALLAS.

Polysticta stelleri (PALLAS). Steller's Eider

Anas stelleri PALLAS, Spic. Zool., vol. 1, fasc. 6, 1769, p. 35, pl. 5.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Genus MELANITTA Boie

Melanitta BOIE, Isis von OKEN, vol. 10, heft 5, May 1822, col. 564. Type, by subs. design., *Anas fusca* LINNAEUS (Eyton, 1838).

Subgenus PELIONETTA Kaup

Pelionetta KAUP, Skizz. Entw.-Ges. Eur. Thierw., 1829, p. 107. Type, by monotypy, *Anas perspicillata* LINNAEUS.

Melanitta perspicillata (LINNAEUS). Surf Scoter

Anas perspicillata LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 125.

Modern form reported from Pleistocene (Upper San Pedro formation): San Pedro, California.

Genus CHENDYTES Miller

Chendytes L. H. MILLER, Condor, vol. 27, No. 4, July 15, 1925, p. 145. Type, by monotypy, *Chendytes lawi* L. H. MILLER,

Chendytes lawi MILLER

Chendytes lawi L. H. MILLER, Condor, vol. 27, No. 4, July 15, 1925, p. 145, fig. 40.

Pleistocene: Lower San Pedro formation, Sexton Canyon near Lake Canyon, Ventura County,[32a] California; and Upper San Pedro formation, near Santa Monica, San Pedro, and Playa del Rey, California.

Subfamily ERISMATURINAE. RUDDY AND MASKED DUCKS

Genus ERISMATURA Bonaparte

Erismatura BONAPARTE, Giornale Arcadico, vol. 52, 1832, p. 208. Type, by monotypy, *Anas rubidus* WILSON.

Erismatura jamaicensis (GMELIN). Ruddy Duck

Anas jamaicensis· GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 519.

Modern form reported from Pleistocene: Venice, Florida; Fossil Lake, Oregon; McKittrick, California.

Subfamily EONESSINAE. EONESSA

Genus EONESSA Wetmore

Eonessa WETMORE, Journ. Pal., 1938, p. 280. Type, by orig. design., *Eonessa anaticula* WETMORE.

Eonessa anaticula WETMORE

Eonessa anaticula WETMORE, Journ. Pal., 1938, p. 280, figs. 1-5.

Eocene: Uinta C horizon of Myton Pocket, Utah.

Subfamily MERGINAE. MERGANSERS

Genus LOPHODYTES Reichenbach

Lophodytes REICHENBACH, Avium Syst. Nat., 1852 (1853), p. ix. Type, by orig. design., *Mergus cucullatus* LINNAEUS.

Lophodytes cucullatus (LINNAEUS). Hooded Merganser

Mergus cucullatus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 129.

Modern form reported from Pleistocene: Itchtucknee River, Florida; Fossil Lake, Oregon.

[32a] Type locality.

Genus MERGUS Linnaeus

Mergus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 129. Type, by subs. design., *Mergus merganser* LINNAEUS (Gray, 1840).

Mergus serrator LINNAEUS. **Red-breasted Merganser**
Mergus Serrator LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 129.

Modern form reported from Pleistocene: Fossil Lake, Oregon; North Shore Channel, Chicago, Illinois.

Order FALCONIFORMES. VULTURES, HAWKS, AND FALCONS

Suborder CATHARTAE. NEW WORLD VULTURES

Family CATHARTIDAE. NEW WORLD VULTURES

Genus CATHARTES Illiger

Cathartes ILLIGER, Prodromus, 1811, p. 236. Type, by subs. design., *Vultur aura* LINNAEUS (Vigors, 1825).

Cathartes aura (LINNAEUS). **Turkey Vulture** [33]
Vultur aura LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 86.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Vero (Stratum 3),[34] Melbourne, and cavern deposits near Lecanto, Florida; Potter Creek and Samwel caves, Shasta County, Hawver Cave, Eldorado County, Carpinteria, McKittrick, Rancho La Brea, Los Angeles, and Upper San Pedro formation, San Pedro, California.

Genus CORAGYPS Le Maout

Coragyps "GEOFFROY MS" LE MAOUT, Hist. Nat. Oiseaux, 1853, pp. 57, 66. Type, by monotypy, *Vultur atratus* WILSON = *Vultur atratus* Meyer.

Coragyps atratus (MEYER). **Black Vulture**
Vultur atratus "BARTRAM" F. A. A. MEYER, Zool. Annalen, vol. 1, 1794, p. 290.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, and cavern deposits near Lecanto, Florida.

---

[33] Wetmore, Smithsonian Misc. Coll., vol. 85, No. 2, Apr. 13, 1931, pp. 4, 6, 7, 23-24, has recorded the small Mexican turkey vulture, *Cathartes aura aura,* from Seminole Field, Pinellas County, Florida. Other reports of this species are mainly of the larger type, of which two races, *septentrionalis* and *teter,* are at present recognized in the United States.

[34] Recorded from Stratum 2 erroneously by Shufeldt, 9th Ann. Rep. Florida State Geol. Surv., 1917, p. 36.

Coragyps occidentalis (MILLER)

> *Catharista occidentalis* L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 5, No. 21, Sept. 10, 1909, p. 306.

Pleistocene: McKittrick, Carpinteria and Rancho La Brea,[35] Los Angeles, California.[36]

Coragyps shastensis (MILLER)

> *Catharista shastensis* L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 16, Oct. 28, 1911, p. 388, fig. 1.

Pleistocene: Potter Creek[35] and Samwel caves, Shasta County, and Hawver Cave, Eldorado County, California.

Genus PHASMAGYPS Wetmore

> *Phasmagyps* WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 3. Type, by monotypy, *Phasmagyps patritus* WETMORE.

Phasmagyps patritus WETMORE

> *Phasmagyps patritus* WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 3, figs. 1-4.

Oligocene (Chadron): Horsetail Creek, Weld County, Colorado.

Genus PALAEOGYPS Wetmore

> *Palaeogyps* WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 5. Type, by monotypy, *Palaeogyps prodromus* WETMORE.

Palaeogyps prodromus WETMORE

> *Palaeogyps prodromus* WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 5, figs. 5-14.

Oligocene (Chadron): Horsetail Creek, Weld County, Colorado.

Genus GYMNOGYPS Lesson

> *Gymnogyps* LESSON, Écho du Monde Savant, ser. 2, vol. 6, Dec. 8, 1842, col. 1037. Type, by monotypy, *Vultur californianus* SHAW.

Gymnogyps californianus (SHAW). **California Condor**

> *Vultur californianus* SHAW, in SHAW AND NODDER, Nat. Misc., vol. 9, 1797, text to pl. 301.

---

[35] Type locality.

[36] Recorded also from deposits that may be late Pleistocene or early Recent in Pit 10 at Rancho La Brea (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43), Conkling Cavern, Pyramid Peak, Organ Mountains, Dona Ana County, New Mexico (Howard, H., and Miller, A. H., Condor, vol. 35, Jan. 15, 1933, pp. 15, 17), and from Smith Creek Cave, 34 miles north of Baker, White Pine County, Nevada (Howard, H., Condor, vol. 37, July 15, 1935, pp. 206-207).

Modern form reported from Pleistocene: Sarasota and Seminole Field, Pinellas County, Florida; Carpinteria and Rancho La Brea, Los Angeles, California.

Gymnogyps amplus MILLER

Gymnogyps amplus L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 16, Oct. 28, 1911, p. 390, fig. 2.

Pleistocene: Samwel Cave, Shasta County, California.

Genus BREAGYPS Miller and Howard

Breagyps ·L. H. MILLER AND H. HOWARD, Publ. Univ. California at Los Angeles Biol. Sci., vol. 9, Feb. 18, 1938, p. 171. Type, by orig. design., *Vultur clarki* MILLER.

Breagyps clarki (MILLER)

Sarcorhamphus clarki L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 1, Nov. 28, 1910, p. 11, figs. 3*a*, 3*b*.

Pleistocene: Rancho La Brea, Los Angeles, California.[37]

Genus SARCORAMPHUS Duméril

Sarcoramphus DUMÉRIL, Zool. Analytique, 1806, p. 32. Type, by subs. design., *Vultur ·papa* LINNAEUS (Froriep, 1806).

Sarcoramphus kernensis (MILLER)

Vultur kernensis L. H. MILLER, Condor, vol. 33, Mar. 18, 1931, p. 70, fig. 16.

Pliocene: Pozo Creek, Kern River Divide, Kern County, about 9 miles northeast of Bakersfield, California.

Family TERATORNITHIDAE. TERATORNITHES

Genus TERATORNIS Miller

Teratornis, L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 5, No. 21, Sept. 10, 1909, p. 307. Type, by monotypy, *Teratornis merriami* MILLER.

Teratornis merriami MILLER

Teratornis merriami L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 5, No. 21, Sept. 10, 1909, p. 307, text figs. 1-9.

Pleistocene: Seminole Field, Pinellas County, and Bradenton, Florida; Rancho La Brea,[38] Los Angeles, McKittrick, and Carpinteria, California.

---

[37] Recorded also by Howard, Condor, vol. 37, July 15, 1935, p. 206, from deposits that may be late Pleistocene or early Recent in Smith Creek Cave, 34 miles north of Baker, White Pine County, Nevada.

[38] Type locality. Recorded also from early Recent deposits in Pit 10, at Rancho La Brea (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43).

Genus CATHARTORNIS Miller [39]

Cathartornis L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 1, Nov. 28, 1910, p. 14. Type, by monotypy, *Cathartornis gracilis* MILLER.

Cathartornis gracilis MILLER

Cathartornis gracilis L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 1, Nov. 28, 1910, p. 14, figs. 4*a*, 4*b*.

Pleistocene: Rancho La Brea, Los Angeles, California.

Suborder FALCONES. SECRETARY-BIRDS, HAWKS, AND FALCONS

Superfamily FALCONOIDEA. HAWKS, FALCONS, AND ALLIES

Family ACCIPITRIDAE. HAWKS, OLD WORLD VULTURES, HARRIERS, AND OSPREYS

Subfamily AEGYPIINAE. OLD WORLD VULTURES

Genus PALAEOBORUS Coues

Palaeoborus COUES, Key N. Amer. Birds, 2d ed., 1884, p. 822. Type, by orig. design., *Cathartes umbrosus* COPE.

Palaeoborus umbrosus (COPE) [40]

Cathartes umbrosus COPE, Proc. Acad. Nat. Sci. Philadelphia, vol. 26, sign. 10, Oct. 20, 1874, p. 151.

Pliocene: North of Pojauque, New Mexico.

Palaeoborus howardae WETMORE

Palaeoborus howardae WETMORE, Proc. U. S. Nat. Mus., vol. 84, Nov. 3, 1936, p. 73, fig. 13.

Miocene: Dawes County, Nebraska.

Palaeoborus rosatus MILLER AND COMPTON

Palaeoborus rosatus A. H. MILLER AND L. V. COMPTON, Condor, vol. 41, July 15, 1939, p. 156, fig. 34B.

Lower Miocene (Rosebud formation): Flint Hill, 9 miles west-southwest of Martin, Bennett County, South Dakota.

---

[39] Allocated to Teratornithidae by Miller, L. H., and Howard, H., Publ. Univ. California at Los Angeles Biol. Sci., vol. 9, Feb. 18, 1938, pp. 169-170, 173.

[40] Placed in Aegypiinae by Howard, Carnegie Inst. Washington, Publ. 349, 1932, pp. 45, 70-73, 75, 76.

Genus NEOGYPS Miller

Neogyps L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 9, No. 9, Mar. 10, 1916, p. 108. Type, by monotypy, *Neogyps errans* MILLER.

Neogyps errans MILLER

Neogyps errans L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 9, No. 9, Mar. 10, 1916, p. 108, fig. 2.

Pleistocene: Rancho La Brea,[41] Los Angeles, Carpinteria, and McKittrick, California.

Genus NEOPHRONTOPS Miller

Neophrontops L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 9, No. 9, Mar. 10, 1916, p. 106. Type, by monotypy, *Neophrontops americanus* MILLER.

Neophrontops americanus MILLER

Neophrontops americanus L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 9, No. 9, Mar. 10, 1916, p. 106, fig. 1.

Pleistocene: Rancho La Brea,[42] Los Angeles, Carpinteria, and McKittrick, California.

Neophrontops dakotensis COMPTON

Neophrontops dakotensis COMPTON, Amer. Journ. Sci., ser. 5, vol. 30, October 1935, p. 344, fig. 1.

Lower Pliocene: Big Spring Canyon, 15 miles southwest of Martin, Bennett County, South Dakota.

Subfamily ELANINAE. WHITE-TAILED KITES

Genus ELANUS Savigny

Elanus SAVIGNY, Descr. de l'Égypte, vol. 1, 1809, pp. 69, 97. Type, by monotypy, *Elanus caesius* SAVIGNY = *Falco melanopterus* DAUDIN.

Elanus leucurus (VIEILLOT). White-tailed Kite

Milvus leucurus VIEILLOT, Nouv. Dict. d'Hist. Nat., nouv. éd., vol. 20, 1818, p. 563 [errore = 556].

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

---

[41] Type locality. Recorded also from early Recent deposits in Pit 10 at this site (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43).

[42] Type locality. Recorded also from early Recent deposits in Pit 10 at this site (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43).

Subfamily MILVINAE. True Kites

Genus PROICTINIA Shufeldt

Proictinia SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16, Aug. 4, 1913, p. 301. Type, by monotypy, *Proictinia gilmorei* SHUFELDT.

Proictinia effera WETMORE

Proictinia effera WETMORE, Bull. Amer. Mus. Nat. Hist., vol. 48, art. 12, Dec. 3, 1923, p. 504, figs. 19-20.

Lower Miocene (Harrison beds): Agate Fossil Quarry, Sioux County, Nebraska.

Proictinia gilmorei SHUFELDT

Proictinia gilmorei SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16, Aug. 4, 1913, p. 301, pl. 55, fig. 27.

Lower Pliocene (Loup Fork formation): Long Island, Phillips County, Kansas.

Subfamily ACCIPITRINAE. Bird Hawks

Genus ASTUR Lacépède

Astur LACÉPÈDE, Tableaux Oiseaux, 1799, p. 4. Type, by subs. design., *Falco palumbarius* LINNAEUS (Vigors, 1824).

Astur atricapillus (WILSON). Goshawk

Falco atricapillus WILSON, Amer. Orn., vol. 6, 1812, p. 80, pl. 52, fig. 3.

Modern form reported from Pleistocene: Carpinteria, and Rancho La Brea, Los Angeles, California.

Genus ACCIPITER Brisson

Accipiter BRISSON, Orn., 1760, vol. 1, p. 28; vol. 6, p. 310. Type, by tautonymy, *Accipiter* BRISSON = *Falco nisus* LINNAEUS.

Accipiter striatus velox (WILSON). Sharp-shinned Hawk [43]

Falco velox WILSON, Amer. Orn., vol. 5, 1812, p. 116, pl. 45, fig. 1.

Modern form reported from Pleistocene: Samwel Cave, Shasta County, Carpinteria, and Rancho La Brea, Los Angeles, California.

Accipiter cooperii (BONAPARTE). Cooper's Hawk

Falco cooperii BONAPARTE, Amer. Orn., vol. 2, 1828, p. 1, pl. 10, fig. 1.

Modern form reported from Pleistocene: McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.

---

[43] The sharp-shinned hawk of continental North America is now considered conspecific with the smaller *Accipiter striatus* of the Greater Antilles.

Subfamily BUTEONINAE. Buzzards and Eagles

Genus BUTEO Lacépède

Buteo LACÉPÈDE, Tableaux Oiseaux, 1799, p. 4. Type, by tautonymy, *Falco buteo* LINNAEUS.

Subgenus BUTEO Lacépède

Buteo jamaicensis (GMELIN). Red-tailed Hawk

Falco jamaicensis GMELIN, Syst. Nat., vol. 1, pt. 1, 1788, p. 266.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Venice, and Melbourne (Stratum 2), Florida; Potter Creek Cave, Shasta County, McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.

Buteo lineatus (GMELIN). Red-shouldered Hawk

Falco lineatus GMELIN, Syst. Nat., vol. 1, pt. 1, 1788, p. 268.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Venice, and Melbourne, Florida; Carpinteria, California.

Buteo platypterus (VIEILLOT). Broad-winged Hawk

Sparvius platypterus VIEILLOT, Tableau Encycl. Méth., vol. 3, 1823, p. 1273.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Buteo swainsoni BONAPARTE. Swainson's Hawk

Buteo swainsoni BONAPARTE, Geogr. and Comp. List, 1838, p. 3.

Modern form reported from Pleistocene: McKittrick, and Rancho La Brea, Los Angeles, California.

Buteo typhoius WETMORE

Buteo typhoius WETMORE, Bull. Amer. Mus. Nat. Hist., vol. 48, art. 12, Dec. 3, 1923, p. 489, figs. 3-5.

Miocene: Lower Harrison beds and Snake Creek beds [44] south of Agate, Sioux County, Nebraska.

Buteo antecursor WETMORE

Buteo antecursor WETMORE, Bull. Mus. Comp. Zoöl., vol. 75, October 1933, p. 298, figs. 1-5.

Upper Oligocene (Brule): Near Torrington, Goshen County, Wyoming.

---

[44] Type locality.

Buteo grangeri WETMORE AND CASE

Buteo grangeri WETMORE AND CASE, Contr. Mus. Pal. Univ. Michigan, vol. 4, No. 8, Jan. 15, 1934, p. 129, 1 pl.

Oligocene (Oreodon beds) : Big Badlands of Pass Creek, Washabaugh County, South Dakota.

Buteo ales (WETMORE)[45]

Geranoaëtus ales WETMORE, Ann. Carnegie Mus., vol. 16, No. 4, Apr. 10, 1926, p. 403, pl. 38, figs. 1-5.

Miocene (Lower Harrison beds) : Quarry No. 2, Agate Springs Fossil Quarries, Sioux County, Nebraska.

Buteo conterminus (WETMORE)

Geranoaëtus conterminus WETMORE, Bull. Amer. Mus. Nat. Hist., vol. 48, art. 12, Dec. 3, 1923, p. 497, figs. 11-13.

Lower Pliocene (Snake Creek beds) ; 20 miles south of Agate, Sioux County, Nebraska.

Buteo contortus (WETMORE)

Geranoaëtus contortus WETMORE, Bull. Amer. Mus. Nat. Hist., vol. 48, art. 12, Dec. 3, 1923, p. 492, figs. 6-9.

Upper Miocene (Snake Creek beds) : Sinclair Draw,[46] and Olcott Hill, Sioux County, Nebraska.

Buteo dananus (MARSH)

Aquila danana MARSH, Amer. Journ. Sci., ser. 3, vol. 2, August 1871, p. 125.

Miocene (Loup Fork) : Loup Fork River, Nebraska.

Subgenus TRIORCHIS Kaup

Triorchis KAUP, Skizz. Entw.-Ges. Eur. Thierw., 1829, p. 84. Type, by monotypy, *Falco lagopus* GMELIN = *Falco lagopus* PONTOPPIDAN.

Buteo lagopus (BRÜNNICH). **Rough-legged Hawk**

Falco lagopus BRÜNNICH, Orn. Bor., 1764, p. 4.

Modern form reported from Pleistocene : Rancho La Brea, Los Angeles, California.

Buteo regalis (GRAY). **Ferruginous Rough-leg**

Archibuteo regalis GRAY, Genera of Birds, vol. 1, pt. 1, May 1844, pl. 6.

Modern form reported from Pleistocene : Hawver Cave, Eldorado County, Rancho La Brea, Los Angeles, and McKittrick, California.

---

[45] *Geranoaëtus,* formerly used for this and certain related species, is now considered a synonym of *Buteo,* according to Wetmore, Auk, 1933, p. 212.

[46] Type locality.

Genus HYPOMORPHNUS Cabanis [47]

Hypomorphnus CABANIS, Arch. Naturg., vol. 10, bd. 1, 1844, p. 263. Type, by orig. design., *Falco urubitinga* LINNAEUS.

Hypomorphnus enecta (WETMORE)

Urubitinga enecta WETMORE, Bull. Amer. Mus. Nat. Hist., vol. 48, art. 12, Dec. 3, 1923, p. 500, figs. 14-18.

Middle Miocene (Sheep Creek beds) : 20 miles south of Agate, Sioux County, Nebraska.

Hypomorphnus milleri (HOWARD)

Urubitinga milleri HOWARD, Carnegie Inst. Washington, Publ. 429, October 1932, p. 25, pl. 2, figs. 3-3a, pl. 3, fig. 2.

Pleistocene : Hawver Cave, Eldorado County, California.

Hypomorphnus fragilis (MILLER) [48]

Geranoaëtus fragilis L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 12, Oct. 9, 1911, p. 315, figs. 5a, 5b.

Pleistocene : McKittrick, Rancho La Brea,[49] Los Angeles, and Carpinteria, California.[50]

Genus WETMOREGYPS Miller

Wetmoregyps L. H. MILLER, Condor, vol. 30, No. 4, July 16, 1928, p. 255. Type, by orig. design., *Morphnus daggetti* MILLER.

Wetmoregyps daggetti (MILLER)

Morphnus daggetti L. H. MILLER, Condor, vol. 17, No. 5, Oct. 10, 1915, p. 179, fig. 63.

Pleistocene : Rancho La Brea,[51] Los Angeles, and Carpinteria, California.

---

[47] For the use of *Hypomorphnus* to replace *Urubitinga* see Peters, Check-list of the birds of the world, vol. 1, 1931, p. 244.

[48] Referred to this group by Howard, Carnegie Inst. Washington, Publ. 429, 1932, pp. 16-25.

[49] Type locality. Recorded also from early Recent deposits in Pit 10 at Rancho La Brea (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43).

[50] Recorded also from late Pleistocene or early Recent deposits in Shelter Cave, Pyramid Peak, Organ Mountains, Dona Ana County, New Mexico, by Howard, H., and Miller, A. H., Condor, vol. 35, 1933, pp. 16, 17.

[51] Type locality.

Genus MORPHNUS Dumont

Morphnus DUMONT, Dict. Sci. Nat., vol. 1, October 1816, p. 88. Type, by
   subs. design., *Falco guianensis* Daudin (Chubb, 1916).

Morphnus woodwardi MILLER

Morphnus woodwardi L. H. MILLER, Univ. California Publ., Bull. Dep. Geol.,
   vol. 6, No. 12, Oct. 9, 1911, p. 312, figs. *3a, 3b*.

Pleistocene: Rancho La Brea, Los Angeles, California.[52]

Genus SPIZAËTUS Vieillot

Spizaëtus VIEILLOT, Analyse, 1816, p. 24. Type, by subs. design., *Falco ornatus*
   DAUDIN (Gray, 1840).

Spizaëtus grinnelli (MILLER)[53]

Geranoaëtus grinnelli L. H. MILLER, Univ. California Publ., Bull. Dep. Geol.,
   vol. 6, No. 12, Oct. 9, 1911, p. 314, figs. 4a, 4b.

Pleistocene: Rancho La Brea,[54] Los Angeles, and Carpinteria,
California.

Spizaëtus willetti HOWARD

Spizaëtus willetti HOWARD, Condor, vol. 37, July 15, 1935, p. 207, fig. 40.

Quaternary (questionably Pleistocene)[55]: Smith Creek Cave, 34
miles north of Baker, White Pine County, Nevada.

Genus AQUILA Brisson [56]

Aquila BRISSON, Orn., 1760, vol. 1, pp. 28, 419. Type, by tautonymy, *Aquila*
   BRISSON = *Falco chrysaëtos* LINNAEUS.

Aquila chrysaëtos (LINNAEUS). Golden Eagle

Falco chrysaëtos LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 88.

Modern form reported from Pleistocene: Fossil Lake, Oregon;
Rancho La Brea, Los Angeles, Carpinteria, and McKittrick, California.

---

[52] Recorded also from early Recent deposits in Pit 10 at this site (Howard, H.,
and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43).

[53] Allocated in *Spizaëtus* by Howard, Carnegie Inst. Washington, Publ. 429,
1932, pp. 33-44.

[54] Type locality. Recorded also from early Recent deposits in Pit 10 at this site
(Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939,
p. 43).

[55] Uncertainty exists as to whether this deposit is late Pleistocene or early
Recent.

[56] *Aquila ferox* Shufeldt, proves to be a mammal. See Wetmore, Amer. Mus.
Nov., No. 680, Dec. 4, 1933, pp. 1-2.

Aquila pliogryps SHUFELDT [56a]

Aquila pliogryps SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 821.

Pleistocene: Fossil Lake, Oregon.

Aquila sodalis SHUFELDT [56a]

Aquila sodalis SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 821.

Pleistocene: Fossil Lake, Oregon.

Genus HALIAEETUS Savigny

Haliaeetus SAVIGNY, Descr. de l'Égypte, vol. 1, 1809, pp. 68, 85. Type, by monotypy, *Haliaeetus nisus* SAVIGNY = *Falco albicilla* LINNAEUS.

Haliaeetus leucocephalus (LINNAEUS). **Bald Eagle**

Falco leucocephalus LINNAEUS, Syst. Nat., 12th ed., vol. 1, 1766, p. 124.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Venice, Melbourne, and cavern deposits near Lecanto, Florida; Niobrara River, near Peters, Sheridan County, Nebraska; Fossil Lake, Oregon; Carpinteria, McKittrick, Rancho La Brea, Los Angeles, and Upper San Pedro, near San Pedro, California.

Subfamily PALAEOPLANCINAE. PALAEOPLANCUS

Genus PALAEOPLANCUS Wetmore

Palaeoplancus WETMORE, Smithsonian Misc. Coll., vol. 87, No. 19, Dec. 26, 1933, p. 1. Type, by orig. design., *Palaeoplancus sternbergi* WETMORE.

Palaeoplancus sternbergi WETMORE

Palaeoplancus sternbergi WETMORE, Smithsonian Misc. Coll., vol. 87, No. 19, Dec. 26, 1933, p. 12, figs. 1-19.

Oligocene (Upper Oreodon beds): East side of Plum Creek, Niobrara County, Wyoming.

Subfamily CIRCINAE. HARRIERS

Genus CIRCUS Lacépède

Circus LACÉPÈDE, Tableaux Oiseaux, 1799, p. 4. Type, by subs. design., *Falco aeruginosus* LINNAEUS (Lesson, 1828).

Circus hudsonius (LINNAEUS). **Marsh Hawk**

Falco hudsonius LINNAEUS, Syst. Nat., 12th ed., vol. 1, 1766, p. 128.

Modern form reported from Pleistocene: Fossil Lake, Oregon; McKittrick, and Rancho La Brea, Los Angeles, California.

[56a] Generic allocation questionable. See Howard, Carnegie Inst. Washington, Publ. No. 429, 1932, pp. 32, 76.

Family PANDIONIDAE. Ospreys [57]

Genus PANDION Savigny

Pandion Savigny, Descr. de l'Égypte, vol. 1, 1809, pp. 69, 95. Type, by mono-typy, *Pandion fluvialis* Savigny = *Falco haliaetus* Linnaeus.

Pandion haliaetus Linnaeus. Osprey

Falco Haliaetus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 91.

Modern form reported from Pleistocene: Melbourne (Stratum 2), and Itchtucknee River, Florida.

Family FALCONIDAE. Caracaras and Falcons

Subfamily POLYBORINAE. Caracaras

Genus POLYBORUS Vieillot

Polyborus Vieillot, Analyse, 1816, p. 22. Type, by monotypy, Caracara, Buffon = *Falco plancus* J. F. Miller.

Polyborus prelutosus prelutosus Howard [58]

Polyborus prelutosus Howard, Carnegie Inst. Washington, Publ. 487, July 7, 1938, p. 226, pls. 1-3.

Pleistocene: Seminole Field, Pinellas County, and Melbourne, Florida; McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.[59]

Subfamily FALCONINAE. Falcons

Genus FALCO Linnaeus

Falco Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 88. Type, by subs. design., *Falco subbuteo* Linnaeus (A. O. U. Comm., 1886).

---

[57] Compton, L. V., Univ. California Publ. Zoöl., vol. 42, 1938, pp. 173-212, on basis of the feather arrangement and the form of the plantar tendons has proposed to remove *Pandion* as a distinct family to the suborder Cathartae. The characters described unquestionably warrant family rank for this strange genus. The American vultures, however, are so highly peculiar that for the present at least it seems to me desirable to recognize the family but to retain the Pandionidae in the suborder Falcones.

[58] For use of trinomial see Howard, H., Condor, 1940, pp. 40-43.

[59] Type locality. Recorded also from early Recent deposits at this site (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43), and from Quaternary deposits in Conkling Cavern, Organ Mountains, New Mexico.

Subgenus HIEROFALCO Cuvier

Hierofalco Cuvier, Règne Animal, vol. 1, 1817 (Dec. 7, 1816), p. 312. Type, by monotypy, *Falco candicans* Gmelin.

Falco mexicanus Schlegel. Prairie Falcon

Falco mexicanus "Lichtenstein" Schlegel, Abh. Geb. Zool., heft 3, 1850, p. 15.

Modern form reported from Pleistocene: McKittrick, and Rancho La Brea, Los Angeles, California.

Falco swarthi Miller

Falco swarthi L. H. Miller, Condor, vol. 29, No. 3, May 15, 1927, p. 152, fig. 54.

Pleistocene: McKittrick, California.

Subgenus RHYNCHODON Nitzsch

Rhynchodon Nitzsch, Obs. Avium Art. Carot. Comm., 1829, p. 20. Type, by subs. design., *Falco peregrinus* Tunstall (A. O. U. Comm., 1886).

Falco peregrinus Tunstall. Duck Hawk

Falco Peregrinus Tunstall, Orn. Brit., 1771, p. 1.

Modern form reported from Pleistocene: Potter Creek Cave, Shasta County, McKittrick, and Rancho La Brea, Los Angeles, California.

Subgenus TINNUNCULUS Vieillot

Tinnunculus Vieillot, Oiseaux Amér. Sept., vol. 1, 1807, p. 39. Type, by subs. design., *Falco columbarius* Linnaeus (Walden, 1872).

Falco columbarius Linnaeus. Pigeon Hawk

Falco columbarius Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 90.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, Los Angeles, California.

Falco ramenta Wetmore

Falco ramenta Wetmore, Proc. U. S. Nat. Mus., vol. 84, Nov. 3, 1936, p. 75, fig. 14.

Miocene: Dawes County, Nebraska.

Subgenus CERCHNEIS Boie

Cerchneis Boie, Isis von Oken, vol. 19, heft 10, October 1826, col. 970. Type, by monotypy, *Falco rupicolus* Daudin.

Falco sparverius Linnaeus. Sparrow Hawk

Falco sparverius Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 90.

Modern form reported from Pleistocene: Cavern deposits near Lecanto, Florida; Samwel and Potter Creek caves, Shasta County, McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.

Order GALLIFORMES. MEGAPODES, CURASSOWS, PHEASANTS, AND HOATZINS

Suborder GALLI. MEGAPODES, CURASSOWS, GROUSE, AND PHEASANTS

Superfamily CRACOIDEA. MEGAPODES AND CURASSOWS

Family GALLINULOIDIDAE. GALLINULOIDES

Genus GALLINULOIDES Eastman

Gallinuloides EASTMAN, Geol. Mag., February 1900, p. 54. Type, by monotypy, *Gallinuloides wyomingensis* EASTMAN.

Gallinuloides wyomingensis EASTMAN

Gallinuloides wyomingensis EASTMAN, Geol. Mag., n. s., pt. 4, vol. 7, No. 2, February, 1900, p. 54, pl. 4.

Eocene (Bridger, Green River Shales): Fossil,[60] and Henry's Fork, Wyoming.

Family CRACIDAE. CURASSOWS, GUANS, AND CHACHALACAS

Subfamily PENELOPINAE. GUANS AND CHACHALACAS

Genus ORTALIS Merrem

Ortalida [= *Ortalis*] MERREM, Avium Rar. Icones et Descrip., vol. 2, 1786, p. 40. Type, by orig. design., *Phasianus motmot* LINNAEUS.

Ortalis phengites WETMORE

Ortalis phengites WETMORE, Bull. Amer. Mus. Nat. Hist., vol. 48, art. 12, Dec. 3, 1923, p. 487, figs. 1-2.

Lower Pliocene (Snake Creek beds): South of Agate, Sioux County, Nebraska.

Ortalis tantala WETMORE

Ortalis tantala WETMORE, Condor, vol. 35, No. 2, Mar. 15, 1933, p. 64, figs. 10-14.

Lower Miocene (Lower Harrison): Carnegie Hill, Sioux County, Nebraska.

---

[60] Type locality.

Superfamily PHASIANOIDEA. Grouse, Pheasants, and Turkeys

Family TETRAONIDAE. Grouse

Genus DENDRAGAPUS Elliot

Dendragapus Elliot, Proc. Acad. Nat. Sci. Philadelphia, vol. 16, No. 1, January-February (April 23), 1864, p. 23. Type, by subs. design., *Tetrao obscurus* Say (Baird, Brewer, and Ridgway, 1874). ·

Dendragapus obscurus (Say). Dusky Grouse

Tetrao obscurus Say, in Long, Exped. Rocky Mts., vol. 2, 1823, p. 14, note.

Modern form reported from Pleistocene: Samwel and Potter Creek caves, Shasta County, California.

Genus BONASA Stephens

Bonasa Stephens, in Shaw, Gen. Zool., vol. 11, pt. 2, August 1819, p. 298. Type, by subs. design., *Tetrao umbellus* Linnaeus (Gray, 1840).

Bonasa umbellus (Linnaeus). Ruffed Grouse [61]

Tetrao umbellus Linnaeus, Syst. Nat., 12th ed., vol. 1, 1766, p. 275.

Modern form reported from Pleistocene: Cave near Frankstown, Pennsylvania; Cumberland Cave, near Corriganville, Alleghany County, Maryland; caves of Tennessee; Potter Creek Cave, Shasta County, California.

Genus TYMPANUCHUS Gloger

Tympanuchus Gloger, Hand- und Hilfsbuch Naturg., 1842 (pp. 1-450, 1841), p. 396. Type, by monotypy, *Tetrao cupido* Linnaeus.

Tympanuchus pallidicinctus (Ridgway). Lesser Prairie Chicken

Cupidonia cupido var. *pallidicincta* Ridgway, Bull. Essex Inst., vol. 5, No. 12, December 1873, p. 199.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Tympanuchus lulli Shufeldt

Tympanuchus lulli Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 69, pl. 12, fig. 90.

? Pleistocene [62]: Hornerstown, New Jersey.

---

[61] *Bonasa ceres* Shufeldt, Bull. Amer. Mus. Nat. Hist., vol. 32, Aug. 4, 1913, p. 299, pl. 55, figs. 18-20, pl. 56, figs. 45-72, from the Pleistocene of the fissure beds of Arkansas is possibly a synonym. On p. 300 of the reference cited the author alludes to it as *Lagopus ceres*.

[62] Cited in the original description as "Post-Pliocene."

·

Genus PEDIOECETES Baird

Pedioecetes BAIRD, in BAIRD, CASSIN AND LAWRENCE, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, pp. xxi, xliv, [*Pediocactes*], pp. 619, 625. Type, by orig. design., *Tetrao phasianellus* LINNAEUS.

Pedioecetes phasianellus (LINNAEUS). Sharp-tailed Grouse

Tetrao Phasianellus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 160.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Pedioecetes lucasi SHUFELDT

Pediocætes lucasi SHUFELDT, Auk, vol. 8, No. 4, October 1891, p. 367.

Pleistocene: Fossil Lake, Oregon.

Pedioecetes nanus SHUFELDT

Pediocætes nanus SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 821.

Pleistocene: Fossil Lake, Oregon.

Genus CENTROCERCUS Swainson

Centrocercus SWAINSON, in SWAINSON AND RICHARDSON, Fauna Bor.-Amer., vol. 2, 1831 (1832), pp. 358, 496. Type, by orig. design., *Tetrao urophasianus* BONAPARTE.

Centrocercus urophasianus (BONAPARTE). Sage Hen

Tetrao urophasianus BONAPARTE, Zool. Journ., vol. 3, No. 10, April-September, 1827, p. 213.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Genus PALAEOTETRIX Shufeldt

Palaeotetrix SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 821. Type, by monotypy, *Palaeotetrix gilli* SHUFELDT.

Palaeotetrix gilli SHUFELDT

Palaeotetrix gilli SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 821.

Pleistocene: Fossil Lake, Oregon.

Genus PALAEALECTORIS Wetmore

Palaealectoris WETMORE, Condor, vol. 32, No. 3, May 15, 1930, p. 152. Type, by monotypy, *Palaealectoris incertus* WETMORE.

Palaealectoris incertus WETMORE

Palaealectoris incertus WETMORE, Condor, vol. 32, No. 3, May 15, 1930, p. 152, figs. 51-53.

Lower Miocene: Agate fossil quarry, near Agate, Sioux County, Nebraska.

Genus PALAEOPHASIANUS Shufeldt

Palaeophasianus Shufeldt, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16, Aug. 4, 1913, p. 291. Type, by monotypy, *Palaeophasianus meleagroides* Shufeldt.

Palaeophasianus meleagroides Shufeldt

Palaeophasianus meleagroides Shufeldt, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16, Aug. 4, 1913, p. 291, pl. 58, figs. 81-84, 86-88.

Eocene (Wasatch [63] and Bridger) : Elk Creek, Big Horn Basin, and Henry's Fork, Wyoming.

Family PHASIANIDAE. Partridges, Quails, and Pheasants

Subfamily ODONTOPHORINAE. American Quails

Genus COLINUS Goldfuss

Colinus Goldfuss, in Schubert, Handb. Naturg., vol. 3 (Zool.), Abt. 2, 1820, p. 220. Type, by monotypy, *Perdix mexicanus,* Caille de la Louisiana, Pl. Enl. 149 = *Tetrao virginianus* Linnaeus.

Colinus virginianus (Linnaeus). Bob-white

Tetrao virginianus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 161.

Modern form reported from Pleistocene : Seminole Field, Pinellas County, Melbourne, and cavern deposits near Lecanto, Florida ; caves of Tennessee.

Colinus eatoni Shufeldt

Colinus eatoni Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 70, pl. 13, fig. 103.

Geologic age uncertain : Western Kansas.

Genus LOPHORTYX Bonaparte

Lophortyx Bonaparte, Geogr. and Comp. List, 1838, p. 42. Type, by subs. design., *Tetrao californicus* Shaw (Gray, 1840).

Lophortyx californica (Shaw). California Quail

Tetrao californicus Shaw, in Shaw and Nodder, Nat. Misc., vol. 9, 1798, text to pl. 345.

Modern form reported from Pleistocene : Hawver Cave, Eldorado County, Carpinteria, McKittrick, Rancho La Brea, Los Angeles and Upper San Pedro formation, San Pedro, California.

---

[63] Described from specimen from the Wasatch of Elk Creek.

Genus OREORTYX Baird

Oreortyx Baird, in Baird, Cassin and Lawrence, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, pp. xxi, xlv, 638, 642. Type, by orig. design., *Ortyx picta* Douglas.

Oreortyx picta (Douglas). Plumed Quail

Ortyx picta Douglas, Trans. Linn. Soc. London, vol. 16, pt. 1, 1829, p. 143.

Modern form reported from Pleistocene: Potter Creek and Samwel caves, Shasta County, and Hawver Cave, Eldorado County, California.

Genus CYRTONYX Gould

Cyrtonyx Gould, Monogr. Odontoph., pt. 1, 1844, pl. 7 and text (also introduction, p. 14, 1850). Type, by subs. design., *Ortyx massena* Lesson = *O. montezumae* Vigors (Gray, 1855).

Cyrtonyx cooki Wetmore

Cyrtonyx cooki Wetmore, Condor, vol. 36, No. 1, Jan. 15, 1934, p. 30, fig. 5.

Upper Miocene (Upper Sheep Creek beds): 17 miles south of Agate, Sioux County, Nebraska.

Subfamily PHASIANINAE. Pheasants

Genus PHASIANUS Linnaeus [64]

Phasianus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 158. Type, by tautonymy, *Phasianus colchicus* Linnaeus.

Phasianus alfhildae Shufeldt

Phasianus alfhildae Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 71.

Geologic age uncertain: 100 feet below horizon of Haystack Butte, Haystack Mountain, Wyoming.

Genus ARCHAEOPHASIANUS Lambrecht

Archaeophasianus Lambrecht, Handb. Palaeorn., 1933, p. 438. Proposed for *Phasianus roberti* Stone, and *Phasianus mioceanus* Shufeldt. Type, not designated.

Archaeophasianus roberti (Stone)

Phasianus roberti Stone, Auk, vol. 32, No. 3, July (June 29), 1915, p. 376.

Upper Oligocene (Middle John Day): Parilina Creek, 6 miles from junction with Beaver Creek, Oregon.

---

[64] Allocation of the following species to the Old World genus *Phasianus* follows the usage of the original describer, and is subject to verification.

Archaeophasianus mioceanus (SHUFELDT)

> *Phasianus mioceanus* SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 60, pl. 13, figs. 94, 96.

Miocene: Chimney Rock and Scott's Bluff, Nebraska.

Family MELEAGRIDIDAE. TURKEYS

Genus MELEAGRIS Linnaeus

> *Meleagris* LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 156. Type, by subs. design., *Meleagris gallopavo* LINNAEUS (Gray, 1840).

Meleagris gallopavo LINNAEUS. **Wild Turkey** [65]

> *Meleagris Gallopavo* LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 156.

Modern form reported from Pleistocene: Hartman's or Crystal Hill Cave, near Stroudsburg, and Durham Cave, near Riegelsville, Bucks County, and caves near Carlisle, Pennsylvania; Ashmore, Coles County, Illinois; caves of Tennessee; fissure beds, Arkansas; Seminole Field, Pinellas County, Sarasota, Bradenton, Itchtuck-nee River, Vero, Melbourne, and cavern deposits at Ocala and Lecanto, Florida; near San Antonio, Socorro County, New Mexico.[66]

Meleagris antiqua MARSH

> *Meleagris antiquus* MARSH, Amer. Journ. Sci., ser. 3, vol. 2, August 1871, p. 126.

Oligocene (White River): "G Ranch," Colorado.

Meleagris celer MARSH

> *Meleagris celer* MARSH, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 261.

Pleistocene: Monmouth County, New Jersey.

Meleagris richmondi SHUFELDT

> *Meleagris richmondi* SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 67, pl. 2, fig. 19.

Pleistocene: near Mission San Jose, Alameda County, California.

Meleagris superba COPE

> *Meleagris superbus* COPE, Trans. Amer. Phil. Soc., n. s., vol. 14, pt. 1, December 1870, p. 239.

Pleistocene: Monmouth County,[67] and Manalapan,[68] New Jersey; Frankstown and Port Kennedy caves, Pennsylvania.

---

[65] *Ardea sellardsi* Shufeldt, 9th Ann. Rep. Florida State Geol. Surv., 1917, p. 38, pl. 2, fig. 15, is a synonym of *Meleagris gallopavo* according to Wetmore, Smithsonian Misc. Coll., vol. 85, No. 2, Apr. 13, 1931, pp. 10-11, 32-33.

[66] Possibly Upper Pliocene.

[67] Type locality.

[68] Type of *Meleagris altus* Marsh, Amer. Journ. Sci., ser. 3, vol. 4, 1872, p. 260.

Meleagris tridens WETMORE

Meleagris tridens WETMORE, Smithsonian Misc. Coll., vol. 85, No. 2, Apr. 13, 1931, p. 33, fig. 13, pl. 6.

Pleistocene: Seminole Field, Pinellas County, Florida.

Genus PARAPAVO Miller

Parapavo L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 9, No. 9, Mar. 10, 1916, p. 96. Type, by monotypy, *Pavo californicus* MILLER.

Parapavo californicus (MILLER)

Pavo californicus L. H. MILLER, Univ. California Publ., Bull. Dep. Geol., vol. 5, No. 19, Aug. 14, 1909, p. 285, pl. 25.

Upper Pliocene: Cita Canyon, Randall County, Texas; Pleistocene: Carpinteria, Rancho La Brea,[69] Los Angeles, and near La Habra, California.

Order GRUIFORMES. CRANES, RAILS, AND ALLIES

Suborder GRUES. CRANES, LIMPKINS, TRUMPETERS, AND RAILS

Superfamily GRUOIDEA. CRANES, LIMPKINS, AND TRUMPETERS

Family GERANOIDIDAE. GERANOIDES

Genus GERANOIDES Wetmore

Geranoides WETMORE, Condor, vol. 35, No. 3, May 15, 1933, p. 115. Type, by orig. design., *Geranoides jepseni* WETMORE.

Geranoides jepseni WETMORE

Geranoides jepseni WETMORE, Condor, vol. 35, No. 3, May 15, 1933, p. 115, fig. 22.

Lower Eocene (Greybull formation): South Elk Creek, Bighorn County, Wyoming.

Family GRUIDAE. CRANES

Subfamily GRUINAE. CRANES

Genus ALETORNIS Marsh [70]

Aletornis MARSH, Amer. Journ. Sci., ser. 3, vol. 14, October 1872, p. 256. Type, by subs. design., *Aletornis nobilis* MARSH (Hay, 1902).

Aletornis bellus MARSH [71]

Aletornis bellus MARSH, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 258.

Eocene (Bridger): Grizzly Buttes, Wyoming.

---

[69] Recorded also from early Recent deposits in Pit 10 at this site (Howard, H., and Miller, A. H., Carnegie Inst. Washington, Publ. 514, 1939, p. 43).

[70] Allocation in the subfamily Gruinae provisional.

[71] Considered by Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, pp. 32, 76, as possibly a species of Scolopacidae, together with *A. gracilis*.

Aletornis gracilis Marsh [71a]

Aletornis gracilis Marsh, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 258.

Eocene (Bridger) : Henry's Fork, Wyoming.

Aletornis nobilis Marsh [72]

Aletornis nobilis Marsh, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 256.

Eocene (Bridger) : Grizzly Buttes, Wyoming.

Aletornis pernix Marsh

Aletornis pernix Marsh, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 256.

Eocene (Bridger) : Henry's Fork, Wyoming.

Genus FULICALETORNIS Lambrecht

Fulicaletornis Lambrecht, Handb. Palaeorn., 1933, p. 479. Type, by monotypy, *Aletornis venustus* Marsh.

Fulicaletornis venustus (Marsh) [73]

Aletornis venustus Marsh, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 257.

Eocene (Bridger) : Henry's Fork, Wyoming.

Genus PARAGRUS Lambrecht

Paragrus Lambrecht, Handb. Palaeorn., 1933, p. 520. Type, by monotypy, *Gallinuloides prentici* Loomis.

Paragrus prentici (Loomis)

Gallinuloides prentici F. B. Loomis, Amer. Journ. Sci., ser. 4, vol. 22, December 1906, p. 481, figs. 1-3.

Eocene (Wasatch) : Head of Elk Creek, 10 miles west of Otto, Wyoming.

[71a] See footnote 71 on preceding page.

[72] Marsh in his original proposal of the genus *Aletornis* included in it five species without selecting a type. From the five in question Hay, U. S. Geol. Surv., Bull. 179, 1902, p. 527, designated *Aletornis nobilis* Marsh the type. Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, 1915, pp. 30, 31, placed *A. nobilis* in *Grus,* and described in the same paper (p. 77) *Grus marshi.* Lambrecht, Handb. Palaeorn., 1933, p. 520, proposed the genus *Protogrus* for *Aletornis nobilis* and *Grus marshi,* without designating a type. Lambrecht's action as regards *A. nobilis* obviously is erroneous as his proposed genus includes the genotype of *Aletornis. Aletornis nobilis,* therefore, is to be listed as above, and pending study *Grus marshi* is included tentatively under *Grus.*

[73] Systematic allocation provisional. Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, pp. 31, 32, 76, placed this species in the genus *Fulica,* the principal basis for Lambrecht's action in making a distinct genus for it.

Genus GRUS Pallas

Grus PALLAS, Misc. Zool., 1766, p. 66. Type, by tautonymy, *Ardea grus* LINNAEUS.

Grus americana (LINNAEUS). Whooping Crane

Ardea americana LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 142.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Itchtucknee River, and Melbourne (Stratum 2), Florida; Rancho La Brea, Los Angeles, California.

Grus canadensis (LINNAEUS). Brown Crane [74]

Ardea canadensis LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 141.

Modern form reported from Pliocene (Upper Snake Creek formation): Sioux County, Nebraska. From ? Pleistocene: Niobrara River, Nebraska,[75] and Grizzly Buttes, Wyoming. From Pleistocene: Rancho La Brea, Los Angeles, and McKittrick, California; Melbourne, Seminole Field, Pinellas County, and Bradenton, Florida.

Grus proavus MARSH

Grus proavus MARSH, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 261.

Pleistocene: Monmouth County, New Jersey.

Grus nannodes WETMORE AND MARTIN

Grus nannodes WETMORE AND MARTIN, Condor, vol. 32, No. 1, Jan. 20, 1930, p. 62, figs. 23-25.

Middle Pliocene (Ogallala formation): Edson beds, Sec. 25, T. 10 S., R. 38 W., Sherman County, Kansas.

Grus marshi SHUFELDT [76]

Grus marshi SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 77, pl. 15, figs. 144-147.

Eocene (Bridger): Henry's Fork, Wyoming.

---

[74] *Grus canadensis* is used as a group name to cover records of cranes of this type from the Pliocene and Pleistocene, including specimens that range in size from the modern little brown crane to the larger races of the sandhill crane.

Grus minor L. H. Miller, Univ. California Publ., Bull. Dep. Geol., vol. 5, August 1910, p. 446, fig. 8, from the Pleistocene of Rancho La Brea, is now considered by the describer as a synonym of *Grus canadensis*.

[75] This specimen, from either Pliocene or Pleistocene deposits, is the basis of *Grus haydeni* Marsh, Amer. Journ. Sci., ser. 2, vol. 49, 1870, p. 214, considered by Wetmore, Amer. Mus. Nov., No. 302, Feb. 29, 1928, p. 4, as a synonym of *Grus canadensis*.

[76] Generic allocation doubtful. See footnote under *Aletornis nobilis* (p. 49).

Family ARAMIDAE. LIMPKINS

Genus ARAMUS Vieillot

Aramus VIEILLOT, Analyse, 1816, p. 58. Type, by monotypy, Courliri, BUF-
FON = *Ardea scolopacea* GMELIN.

Aramus pictus (MEYER). Limpkin

Tantalus pictus "BARTRAM" F. A. A. MEYER, Zool. Annalen, vol. 1, 1794,
p. 287.

Modern form reported from Pleistocene: Seminole Field, Pinellas
County, and Itchtucknee River, Florida.

Genus BADISTORNIS Wetmore

Badistornis WETMORE, Journ. Morph., vol. 66, Jan. 2, 1940, p. 30. Type, by
orig. design., *Badistornis aramus* WETMORE.

Badistornis aramus WETMORE

Badistornis aramus WETMORE, Journ. Morph., vol. 66, Jan. 2, 1940, p. 30,
figs. 7-10.

Oligocene (*Metamynodon* zone, Brule beds): 35 miles southwest
of Scenic, South Dakota.

Genus ARAMORNIS Wetmore

Aramornis WETMORE, Amer. Mus. Nov., No. 211, Mar. 11, 1926, p. 1. Type,
by orig. design., *Aramornis longurio* WETMORE.

Aramornis longurio WETMORE

Aramornis longurio WETMORE, Amer. Mus. Nov., No. 211, Mar. 11, 1926,
p. 1, figs. 1-4.

Early Middle Miocene (*Merychippus primus* zone of Sheep Creek
beds): Snake Creek Quarries, Sioux County, Nebraska.

Superfamily RALLOIDEA. RAILS

Family RALLIDAE. RAILS, GALLINULES, AND COOTS

Subfamily RALLINAE. RAILS

Genus TELMATORNIS Marsh [77]

Telmatornis MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 210.
Type, by subs. design., *Telmatornis priscus* MARSH (Hay, 1902).

Telmatornis affinis MARSH

Telmatornis affinis MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870,
p. 211.

Eocene (Hornerstown): Hornerstown, New Jersey.

---

[77] Allocation in the subfamily Rallinae provisional.

Telmatornis priscus MARSH

Telmatornis priscus MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 210.

Eocene (Hornerstown) : Hornerstown, New Jersey.

Telmatornis rex SHUFELDT

Telmatornis rex SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 27, pl. 13, fig. 101.

Eocene : Hornerstown, New Jersey.

Genus PALAEORALLUS Wetmore

Palaeorallus WETMORE, Condor, vol. 33, No. 3, May 15, 1931, p. 108. Type, by orig. design., *Palaeorallus troxelli* WETMORE.

Palaeorallus troxelli WETMORE

Palaeorallus troxelli WETMORE, Condor, vol. 33, No. 3, May 15, 1931, p. 108, figs. 26-29.

Eocene (Wasatch) : Northwest of Little Tatman Mountain, near Burlington, Wyoming.

Genus CRECCOIDES Shufeldt

Creccoides SHUFELDT, in COPE, Proc. Amer. Phil. Soc., vol. 30, Apr. 14, 1892, p. 125. Type, by monotypy, *Creccoides osbornii* SHUFELDT.

Creccoides osbornii SHUFELDT

Creccoides osbornii SHUFELDT, Proc. Amer. Phil. Soc., vol. 30, Apr. 14, 1892, p. 125.

Pliocene : Blanco Canyon, Crosby County, Texas.

Genus RALLUS Linnaeus

Rallus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 153. Type, by subs. design., *Rallus aquaticus* LINNAEUS (Fleming, 1821).

Rallus elegans AUDUBON. **King Rail**

Rallus elegans AUDUBON, Birds Amer. (folio), vol. 3, 1834, pl. 203.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, and Itchtucknee River, Florida.

Rallus longirostris BODDAERT. **Clapper Rail**

Rallus longirostris BODDAERT, Table Pl. Enl., 1783, p. 52.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Rallus limicola VIEILLOT. **Virginia Rail**

Rallus limicola VIEILLOT, Nouv. Dict. d'Hist. Nat., nouv. éd., vol. 28, 1819, p. 558.

Modern form recorded from Pleistocene: McKittrick, California.

Genus ARAMIDES Pucheran

Aramides PUCHERAN, Rev. Zool., vol. 8, August 1845, p. 277. Type, by
 subs. design., *Rallus cayanensis* GMELIN (Gray, 1855).

Aramides cajanea (MÜLLER). **Wood Rail**

Fulica cajanea MÜLLER, Natursyst. Suppl., 1776, p. 119.

Modern form reported from Pleistocene : Seminole Field, Pinellas
County, Florida.

Subfamily GALLINULINAE. GALLINULES

Genus GALLINULA Brisson

Gallinula BRISSON, Orn., 1760, vol. 1, p. 50; vol. 6, p. 2. Type, by tautonymy,
 Gallinula BRISSON = *Fulica chloropus* LINNAEUS.

Gallinula chloropus (LINNAEUS). **Florida Gallinule**

Fulica chloropus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 152.

Modern form reported from Upper Pliocene (Hagerman Lake
beds) : Near Hagerman, Idaho. From Pleistocene : Seminole Field,
Pinellas County, and Itchtucknee River, Florida.

Genus PALAEOCREX Wetmore [78]

Palaeocrex WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July
 15, 1927, p. 9. Type, by monotypy, *Palaeocrex fax* WETMORE.

Palaeocrex fax WETMORE

Palaeocrex fax WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2,
 July 15, 1927, p. 9, figs. 15-18.

Oligocene (Chadron) : Horsetail Creek, Weld County, Colorado.

Genus EOCREX Wetmore

Eocrex WETMORE, Condor, vol. 33, No. 3, May 15, 1931, p. 107. Type, by
 orig. design., *Eocrex primus* WETMORE.

Eocrex primus WETMORE

Eocrex primus WETMORE, Condor, vol. 33, No. 3, May 15, 1931, p. 107, figs.
 21-25.

Eocene (Wasatch) : Near Steamboat Springs, Sweetwater County,
Colorado (Sec. 13, T. 24 N., R. 102 W., in Cathedral Bluffs).

---

[78] Subfamily allocation provisional.

Subfamily FULICINAE. Coots

Genus FULICA Linnaeus

Fulica LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 152. Type, by subs. design., *Fulica atra* LINNAEUS (Gray, 1840).

Fulica minor SHUFELDT[79]

Fulica minor SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 820.

Pleistocene: Fossil Lake, Oregon.

Fulica americana GMELIN. American Coot

Fulica americana GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 704.

Modern form recorded from Pleistocene: Seminole Field, Pinellas County, Bradenton, and Itchtucknee River, Florida; Hemphill County, Texas; Fossil Lake, Oregon; Rancho La Brea, Los Angeles, California.

Suborder CARIAMAE. Cariamas and Allies

Family BATHORNITHIDAE. Bathornithes

Genus BATHORNIS Wetmore

Bathornis WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 11. Type, by monotypy, *Bathornis veredus* WETMORE.

Bathornis veredus WETMORE

Bathornis veredus WETMORE, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 11, figs. 19-24.

Oligocene (Chadron): Horsetail Creek, Weld County, Colorado;[80] near Crawford, Nebraska; Indian Creek, Pennington County, South Dakota.

Bathornis celeripes WETMORE

Bathornis celeripes WETMORE, Bull. Mus. Comp. Zoöl., vol. 75, October 1933, p. 302, figs. 6-14.

Upper Oligocene (Brule): Near Torrington, Goshen County, Wyoming[80]; 12 miles northwest of Crawford, Nebraska.

Bathornis cursor WETMORE

Bathornis cursor WETMORE, Bull. Mus. Comp. Zoöl., vol. 75, October 1933, p. 310, figs. 15-19.

Upper Oligocene (Brule): Near Torrington, Goshen County, Wyoming.

---

[79] Doubtfully distinct from *Fulica americana,* according to Compton, Condor, 1934, p. 41.

[80] Type locality.

Order DIATRYMIFORMES. DIATRYMAS

Family DIATRYMIDAE. DIATRYMAS

Genus BARORNIS Marsh

Barornis MARSH, Amer. Journ. Sci., ser. 3, vol. 48, 1894, p. 344. Type, by monotypy, *Barornis regens* MARSH.

Barornis regens MARSH [81]

Barornis regens MARSH, Amer. Journ. Sci., ser. 3, vol. 48, October 1894, p. 344, text fig.

Eocene: "Squankum," New Jersey.

Genus DIATRYMA Cope

Diatryma COPE, Proc. Acad. Nat. Sci. Philadelphia, vol. 28, sign. 2, April 18, 1876, p. 11. Type, by monotypy, *Diatryma gigantea* COPE.

Diatryma ajax SHUFELDT

Diatryma ajax SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16, Aug. 4, 1913, p. 287, pls. 52, figs. 4-5, 53, figs. 8-10, 54, figs. 13-14.

Lower Eocene (basal Wasatch): 3 [82] and 5 miles southeast of mouth of Pat O'Hara Creek, Clark's Fork Basin, Wyoming.

Diatryma giganteum COPE

Diatryma gigantea COPE, Proc. Acad. Nat. Sci. Philadelphia, vol. 28, sign. 2, April 18, 1876, p. 11.

Lower Eocene (Lower Wasatch): New Mexico. [83]

Diatryma steini MATTHEW AND GRANGER

Diatryma steini MATTHEW AND GRANGER, Bull. Amer. Mus. Nat. Hist., vol. 37, art. 11, May 28, 1917, p. 322, pls. 20-33.

Lower Eocene (Gray Bull horizon, Lower Wasatch): South Elk Creek, Bighorn Basin, Wyoming.

Genus OMORHAMPHUS Sinclair

Omorhamphus SINCLAIR, Proc. Amer. Phil. Soc., vol. 67, 1928, p. 51. Type, by monotypy, *Omorhamphus storchii* Sinclair.

Omorhamphus storchii SINCLAIR

Omorhamphus storchii SINCLAIR, Proc. Amer. Phil. Soc., vol. 67, 1928, p. 52, pls. 1-2, figs. 1-3.

---

[81] Considered a species of *Diatryma* by Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, pp. 37-38.

[82] Type locality.

[83] Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 34, refers a fragment in Peabody Museum, Yale University, from Island Point, North Horseshoe, Gallina, New Mexico, to this species.

Lower Eocene (Lower Gray Bull horizon, Lower Wasatch) : $1\frac{1}{2}$ miles southeast of Dorsey Creek, about 2 miles south of Otto-Basin Road, Bighorn County, Wyoming.

Order CHARADRIIFORMES. Shore-Birds, Gulls, and Auks

Suborder CHARADRII. Shore-birds

Superfamily CHARADRIOIDEA. Plovers, Sandpipers, and Allies

Family HAEMATOPODIDAE. Oyster-catchers

Genus PARACTIORNIS Wetmore

Paractiornis Wetmore, Condor, vol. 32, No. 3, May 15, 1930, p. 153. Type, by monotypy, *Paractiornis perpusillus* Wetmore.

Paractiornis perpusillus Wetmore

Paractiornis perpusillus Wetmore, Condor, vol. 32, No. 3, May 15, 1930, p. 153, figs. 54-56.

Lower Miocene : Carnegie Hill, Agate Fossil Quarry, near Agate, Sioux County, Nebraska.

Family CHARADRIIDAE. Plovers, Turnstones, and Surf-birds

Subfamily CHARADRIINAE. Plovers

Genus CHARADRIUS Linnaeus

Charadrius Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 150. Type, by tautonymy, *Charadrius hiaticula* Linnaeus.

Charadrius sheppardianus Cope [84]

Charadrius sheppardianus Cope, Bull. Geol. and Geogr. Surv. Terr., vol. 6, No. 1, Feb. 11, 1881, p. 83.

Upper Miocene (Florissant) : Florissant, Colorado.

Genus EUPODA Brandt

Eupoda Brandt, in Tchihatcheff, Voy. Sci. Altai Orient., 1845, p. 444. Type, by monotypy, *Charadrius asiaticus* Pallas.

Eupoda montana (Townsend). Mountain Plover

Charadrius montanus J. K. Townsend, Journ. Acad. Nat. Sci. Philadelphia, vol. 7, pt. 2, Nov. 21, 1837, p. 192.

Modern form reported from Pleistocene : McKittrick, California.

---

[84] Subgeneric relationships not certain.

Genus OXYECHUS Reichenbach

Oxyechus REICHENBACH, Avium Syst. Nat., 1852 (1853), p. xviii. Type, by orig. design., *Charadrius vociferus* LINNAEUS.

Oxyechus vociferus (LINNAEUS). Killdeer

Charadrius vociferus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 150.

Modern form reported from Pleistocene: McKittrick, and Rancho La Brea, Los Angeles, California.

Genus SQUATAROLA Cuvier

Squatarola CUVIER, Règne Animal, vol. 1, 1817 (Dec. 7, 1816), p. 467. Type, by tautonymy, *Tringa squatarola* LINNAEUS.

Squatarola squatarola (LINNAEUS). Black-bellied Plover

Tringa squatarola LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 149.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Genus LIMICOLAVIS Shufeldt [85]

Limicolavis SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 55. Type, by monotypy, *Limicolavis pluvianella* SHUFELDT.

Limicolavis pluvianella SHUFELDT

Limicolavis pluvianella SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 55, pl. 15, fig. 129.

? Oligocene: Lower Willow Creek, Oregon.

Family SCOLOPACIDAE. SNIPE, WOODCOCK, AND SANDPIPERS

Subfamily PALAEOTRINGINAE. PALAEOTRINGAS

Genus PALAEOTRINGA Marsh

Palaeotringa MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 208. Type, by subs. design., *Palaeotringa littoralis* MARSH (Hay, 1902).

Palaeotringa littoralis MARSH [87]

Palaeotringa littoralis MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 208.

Eocene (Hornerstown): Hornerstown, New Jersey.

---

[85] Family relationship not entirely certain.

[87] Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, pp. 23, 77, pl. 6, fig. 35, believes this to be a gull, but this is open to question.

Palaeotringa vagans Marsh

> *Palaeotringa vagans* Marsh, Amer. Journ. Sci., ser. 3, vol. 3, May 1872, p. 365.

Eocene (Hornerstown) : Hornerstown, New Jersey.

Palaeotringa vetus Marsh

> *Palaeotringa vetus* Marsh, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 209.

Eocene (Hornerstown) : Arneytown, New Jersey.

Subfamily SCOLOPACINAE. Woodcock and Snipe

Genus CAPELLA Frenzel

> *Capella* Frenzel, Beschr. Vögel und Eyer Wittenberg, 1801, p. 58. Type, by monotypy, *Scolopax coelestis* Frenzel = *Scolopax gallinago* Linnaeus.

Capella delicata (Ord). **Wilson's Snipe**

> *Scolopax delicata* Ord, in reprint Wilson, Amer. Orn., vol. 9, 1825, p. ccxviii.

Modern form reported from Pleistocene : Rancho La Brea, Los Angeles, California.

Subfamily NUMENIINAE. Curlews, Yellow-legs, and Allies

Genus TOTANUS Bechstein

> *Totanus* Bechstein, Orn. Taschenb. Deutschl., vol. 2, 1803, p. 282. Type, by tautonymy, *Totanus maculatus* Bechstein = *Scolopax totanus* Linnaeus.

Totanus melanoleucus (Gmelin). **Greater Yellow-legs**

> *Scolopax melanoleuca* Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 659.

Modern form reported from Pleistocene : Rancho La Brea, Los Angeles, and McKittrick, California.

Genus NUMENIUS Brisson

> *Numenius* Brisson, Orn., 1760, vol. 1, p. 48; vol. 5, p. 311. Type, by tautonymy, *Numenius* Brisson = *Scolopax arquata* Linnaeus.

Numenius americanus Bechstein. **Long-billed Curlew**

> *Numenius americanus* Bechstein, in Latham, Allgem. Ueb. Vögel, vol. 4, pt. 2, 1812, p. 432.

Modern form reported from Pleistocene : McKittrick, and Rancho La Brea, Los Angeles, California.

Genus PHAEOPUS Cuvier

Phaeopus CUVIER, Règne Animal, vol. 1, 1817 (Dec. 7, 1816), p. 485. Type, by tautonymy, *Scolopax phaeopus* LINNAEUS.

Phaeopus hudsonicus (LATHAM). **Hudsonian Curlew**

Numenius hudsonicus LATHAM, Index Orn., vol. 2, 1790, p. 712.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Subfamily CALIDRIINAE. SANDPIPERS, GODWITS, AND ALLIES

Genus PELIDNA Cuvier

Pelidna CUVIER, Règne Animal, vol. 1, 1817 (Dec. 7, 1816), p. 490. Type, by subs. design., *Tringa cinclus* LINNAEUS, 1766 = *Tringa alpina* LINNAEUS, 1758 (Gray, 1840).

Pelidna alpina (LINNAEUS). **Red-backed Sandpiper**

Tringa alpina LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 149.

Modern form reported from Pleistocene: McKittrick, California.

Genus LIMNODROMUS Wied

Limnodromus WIED, Beitr. Naturg. Brasil, vol. 4, Abt. 2, 1833, p. 716. Type, by monotypy, *Scolopax grisea* GMELIN.

Limnodromus griseus (GMELIN). **Dowitcher**

Scolopax grisea GMELIN, Syst. Nat., vol. 1, pt. 2, 1789, p. 658.

Modern form reported from Pleistocene: McKittrick, and Rancho La Brea, Los Angeles, California.

Genus MICROPALAMA Baird

Micropalama BAIRD, in BAIRD, CASSIN, AND LAWRENCE, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, pp. xxii, xlvii, 714, 726. Type, by orig. design., *Tringa himantopus* BONAPARTE.

Micropalama hesternus WETMORE

Micropalama hesternus WETMORE, Proc. U. S. Nat. Mus., vol. 64, art. 5, Jan. 15, 1924, p. 11, figs. 6-7.

Upper Pliocene: Two miles south of Benson, Arizona.

Genus LIMOSA Brisson

Limosa BRISSON, Orn., 1760, vol. 1, p. 261; vol. 5, p. 48. Type, by tautonymy, *Limosa* BRISSON = *Scolopax limosa* LINNAEUS.

Limosa vanrossemi MILLER

Limosa vanrossemi L. H. MILLER, Carnegie Inst. Washington, Publ. 349, August 1925, p. 116, pl. 6.

Miocene (Temblor, *Turritella ocoyana* zone): Lompoc, California.

Family RECURVIROSTRIDAE. Avocets and Stilts

Genus RECURVIROSTRA Linnaeus

Recurvirostra Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 151. Type, by monotypy, *Recurvirostra avosetta* Linnaeus.

Recurvirostra americana Gmelin. Avocet

Recurvirostra americana Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 693.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, and McKittrick, California.

Family PRESBYORNITHIDAE. Presbyornithes

Genus PRESBYORNIS Wetmore

Presbyornis Wetmore, Ann. Carnegie Mus., vol. 16, Apr. 10, 1926, p. 396. Type, by monotypy, *Presbyornis pervetus* Wetmore.

Presbyornis pervetus Wetmore

Presbyornis pervetus Wetmore, Ann. Carnegie Mus., vol. 16, Apr. 10, 1926, p. 396, pl. 37, figs. 10-20.

Eocene (Lower Green River formation): White River, Utah, 2 miles from Colorado State line.

Family PHALAROPODIDAE. Phalaropes

Genus LOBIPES Cuvier

Lobipes Cuvier, Règne Animal, vol. 1, 1817 (Dec. 7, 1816), p. 495. Type, by orig. design., *Tringa hyperborea* Linnaeus = *Tringa lobata* Linnaeus.

Lobipes lobatus (Linnaeus). Northern Phalarope

Tringa tobata [sic] Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 148.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Suborder LARI. Gulls, Terns, and Skimmers

Family LARIDAE. Gulls and Terns

Subfamily LARINAE. Gulls

Genus LARUS Linnaeus [88]

Larus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 136. Type, by subs. design., *Larus canus* Linnaeus (Selby, 1840).

---

[88] *Larus vero* Shufeldt (Journ. Geol., January-February 1917, p. 18), has been identified by Wetmore as *Nyctanassa violacca* Linnaeus (Smithsonian Misc. Coll., vol. 85, No 2, Apr. 13, 1931, p. 16).

Subgenus LARUS Linnaeus

Larus glaucescens NAUMANN. **Glaucous-winged Gull**

Larus glaucescens NAUMANN, Naturg. Vögel Deutschl., vol. 10, 1840, p. 351.

Modern form reported from Pleistocene (Upper San Pedro) : Near San Pedro, California.

Larus argentatus PONTOPPIDAN. **Herring Gull**

Larus argentatus PONTOPPIDAN, Danske Atlas, vol. 1, 1763, p. 622.

Modern form reported from Pleistocene : Fossil Lake, Oregon.[89]

Larus oregonus SHUFELDT [90]

Larus oregonus SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 820.

Pleistocene : Fossil Lake, Oregon.

Larus pristinus SHUFELDT [91]

Larus pristinus SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, p. 54, pl. 14, fig. 112.

? Oligocene (John Day) : Willow Creek, Oregon.

Larus robustus SUHFELDT [90]

Larus robustus SHUFELDT, Amer. Nat., vol. 25, No. 297, September 1891, p. 819.

Pleistocene : Fossil Lake, Oregon.

Subgenus CHROICOCEPHALUS Eyton

Chroicocephalus EYTON, Hist. Rarer Brit. Birds, 1836, p. 57. Type, by subs. design., *Larus capistratus* TEMMINCK = *L. ridibundus* LINNAEUS (Gray, 1840).

Larus philadelphia (ORD). **Bonaparte's Gull**

Sterna philadelphia ORD, in GUTHRIE, Geogr., 2d Amer. ed., 1815, p. 319.

Modern form reported from Pleistocene : Fossil Lake, Oregon.

Genus XEMA Leach

Xema LEACH, in Ross, Voyage Discovery, 1819, app., p. lvii. Type, by mono-typy, *Larus sabini* SABINE.

Xema sabini (SABINE). **Sabine's Gull**

Larus sabini J. SABINE, Trans. Linn. Soc. London, vol. 12, pt. 2, 1819, p. 522, pl. 29.

Modern form reported from Pleistocene : Fossil Lake, Oregon.

---

[89] Through a *lapsus calami* listed from the Pleistocene of Florida by Wetmore, Proc. 8th Int. Orn. Congr., Amsterdam, 1930, July 1931, p. 481.

[90] Subgeneric allocation provisional.

[91] Generic assignation in original description tentative.

Subfamily STERNINAE. Terns

Genus CHLIDONIAS Rafinesque

Chlidonias Rafinesque, Kentucky Gazette, n. s., vol. 1, No. 8, Feb. 21, 1822, p. 3, col. 5. Type, by monotypy, *Chlidonias melanops* Rafinesque = *Sterna surinamensis* Gmelin.

Chlidonias nigra (Linnaeus). Black Tern

Sterna nigra Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 137.

Modern form reported from Pleistocene: Fossil Lake, Oregon.

Suborder ALCAE. Auks

Family ALCIDAE. Auks, Auklets, and Murres

Subfamily NAUTILORNITHINAE. Nautilornithes

Genus NAUTILORNIS Wetmore

Nautilornis Wetmore, Ann. Carnegie Mus., vol. 16, Apr. 10, 1926, p. 392. Type, by orig. design., *Nautilornis avus* Wetmore.

Nautilornis avus Wetmore

Nautilornis avus Wetmore, Ann. Carnegie Mus., vol. 16, Apr. 10, 1926, p. 392, pl. 36, figs. 1-8.

Eocene (Lower Green River formation) : White River, Utah, 2 miles from Colorado State line.

Nautilornis proavitus Wetmore

Nautilornis proavitus Wetmore, Ann. Carnegie Mus., vol. 16, Apr. 10, 1926, p. 394, pl. 36, fig. 9.

Eocene (Lower Green River formation) : White River, Utah, 2 miles from Colorado State line.

Genus HYDROTHERIKORNIS Miller

Hydrotherikornis A. H. Miller, Univ. California Publ., Bull. Dep. Geol. Sci., vol. 20, No. 3, Apr. 21, 1931, p. 24. Type, by orig. design., *Hydrotherikornis oregonus* Miller.

Hydrotherikornis oregonus Miller

Hydrotherikornis oregonus A. H. Miller, Univ. California Publ., Bull. Dep. Geol. Sci., vol. 20, No. 3, Apr. 21, 1931, p. 24, fig. 1.

Upper Eocene (Arago series) : Sunset Bay, near Coos Bay, Coos County, Oregon.

Subfamily ALCINAE. AUKS AND MURRES

Genus URIA Brisson

Uria BRISSON, Orn., 1760, vol. I, p. 52; vol. 6, p. 70. Type, by tautonymy, *Uria* BRISSON = *Colymbus aalge* PONTOPPIDAN.

Uria affinis (MARSH).

Catarractes affinis MARSH, Amer. Journ. Sci., ser 3, vol. 4, October 1872, p. 259.

Pleistocene: Railroad cut on bank of Penobscot River, near Bangor, Maine.

Uria antiqua (MARSH)

Catarractes antiquus MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 213.

Miocene: Tarboro, Edgecombe County, North Carolina.

Uria aalge (PONTOPPIDAN). Murre

Colymbus aalge PONTOPPIDAN, Danske Atlas, vol. I, 1763, p. 621, pl. 26.

Modern form reported from Pleistocene (Upper San Pedro): Near Playa del Rey, California.

Genus MANCALLA Lucas

Mancalla LUCAS, Proc. U. S. Nat. Mus., vol. 24, art. 1245, Sept. 27, 1901, p. 133. Type, by orig. design., *Mancalla californiensis* LUCAS.

Mancalla californiensis LUCAS

Mancalla californiensis LUCAS, Proc. U. S. Nat. Mus., vol. 24, art. 1245, Sept. 27, 1901, p. 133, figs. 1-2.

Pliocene: Third Street tunnel, Los Angeles,[62] and San Diego formation, San Diego, California.

Genus MIOCEPPHUS Wetmore

Miocepphus WETMORE, Journ. Morph., vol. 66, Jan. 2, 1940, p. 35. Type, by orig. design., *Miocepphus mcclungi* WETMORE.

Miocepphus mcclungi WETMORE

Miocepphus mcclungi WETMORE, Journ. Morph., vol. 66, Jan. 2, 1940, p. 35, figs. 11-14.

Miocene (zone 12, Calvert formation): Near the mouth of Parker Creek, Calvert County, Maryland.

---

[62] Type locality.

Genus SYNTHLIBORAMPHUS Brandt

Synthliboramphus Brandt, Bull. Sci. Acad. Imp. Sci. St. Pétersburg, vol. 2, No. 22, Mar. 19, 1837, col. 347. Type, by subs. design., *Alca antiqua* Gmelin (Gray, 1840).

Synthliboramphus antiquus (Gmelin). Ancient Murrelet

Alca antiqua Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 554.

Modern form reported from Pleistocene (Upper San Pedro formation) : San Pedro, California.

Genus CERORHINCA Bonaparte

Cerorhinca Bonaparte, Ann. Lyc. Nat. Hist. New York, vol. 2, 1828, p. 427. Type, by monotypy, *Cerorhinca occidentalis* Bonaparte = *Alca monocerata* Pallas.

Cerorhinca dubia Miller

Cerorhinca dubia L. H. Miller, Carnegie Inst. Washington, Publ. 349, August 1925, p. 115, pl. 2.

Miocene (Temblor, *Turritella ocoyana* zone) : Lompoc, California.

Genus PLIOLUNDA Miller

Pliolunda L. H. Miller, San Diego Soc. Nat. Hist., vol. 8, Dec. 15, 1937, p. 376. Type, by monotypy, *Pliolunda diegense* Miller.

Pliolunda diegense Miller

Pliolunda diegense L. H. Miller, San Diego Soc. Nat. Hist., vol. 8, Dec. 15, 1937, p. 376, 2 figs.

Upper Middle Pliocene (San Diegan formation) : Market Street, near Euclid Ave., San Diego, California.

Order COLUMBIFORMES. Sand-grouse, Pigeons, and Doves

Suborder COLUMBAE. Pigeons and Doves

Family COLUMBIDAE. Pigeons and Doves

Genus COLUMBA Linnaeus

Columba Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 162. Type, by subs. design., *Columba oenas* Linnaeus (Vigors, 1825).

Subgenus CHLOROENAS Reichenbach

Chloroenas Reichenbach, Avium Syst. Nat., 1852 (1853), p. xxv. Type, by monotypy, *Columba monilis* Vigors = *Columba fasciata* Say.

Columba micula (Wetmore)

Chloraenas micula Wetmore, Proc. U. S. Nat. Mus., vol. 64, art. 5, Jan. 15, 1924, p. 13, figs. 8-9.

Upper Pliocene : 14 miles southeast of Benson, Arizona.

Columba fasciata SAY. **Band-tailed Pigeon**

> *Columba fasciata* SAY, in LONG, Exped. Rocky Mts., vol. 2, 1823, p. 10, note.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, and Carpinteria, California.

Genus ZENAIDURA Bonaparte

> *Zenaidura* BONAPARTE, Consp. Avium, vol. 2, sign. 11, Dec. 10, 1854 (Apr. 15, 1855), p. 84. Type, by monotypy, *Columba carolinensis* LINNAEUS.

Zenaidura macroura (LINNAEUS). **Mourning Dove**

> *Columba macroura* LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 164.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida; McKittrick, and Rancho La Brea, Los Angeles, California.

Genus ECTOPISTES Swainson

> *Ectopistes* SWAINSON, Zool. Journ., vol. 3, 1827, p. 362. Type, by subs. design., *Columba migratoria* LINNAEUS (Gray, 1840).

Ectopistes migratorius (LINNAEUS). **Passenger Pigeon**

> *Columba migratoria* LINNAEUS, Syst Nat., 12th ed., vol. 1, 1766, p. 285.

Modern form reported from Pleistocene: Cave deposits of Tennessee; Rancho La Brea, Los Angeles, California.

Order PSITTACIFORMES. PARROTLIKE BIRDS

Family PSITTACIDAE. LORIES, PARROTS, AND MACAWS

Subfamily ARINAE. PAROQUETS AND MACAWS

Genus CONUROPSIS Salvadori

> *Conuropsis* SALVADORI, Cat. Birds Brit. Mus., vol. 20, 1891, pp. 146, 203. Type, by orig. design., *Psittacus carolinensis* LINNAEUS.

Conuropsis fratercula WETMORE

> *Conuropsis fratercula* WETMORE, Amer. Mus. Nov., No. 211, Mar. 11, 1926, p. 3, figs. 5-6.

Middle Miocene (*Merychippus primus* zone, Sheep Creek beds): Snake Creek Quarries, Sioux County, Nebraska.

Order CUCULIFORMES. Plantain-eaters and Cuckoos

Suborder CUCULI. Cuckoos, Road-runners, and Anis

Family CUCULIDAE. Cuckoos, Road-runners, and Anis

Subfamily NEOMORPHINAE. Road-runners

Genus GEOCOCCYX Wagler

Geococcyx Wagler, Isis von Oken, vol. 24, heft 5, May 1831, col. 524.
Type, by monotypy, *Geococcyx variegata* Wagler = *Saurothera californiana* Lessson.

Geococcyx californianus (Lesson). Road-runner

Saurothera californiana Lesson, Compl. Oeuvres Buffon, vol. 6, 1829, p.
420.

Modern form reported from Pleistocene: Rancho La Brea, Los
Angeles, McKittrick, and Carpinteria, California.

Geococcyx conklingi Howard

Geococcyx conklingi Howard, Condor, vol. 33, No. 5, Sept. 15, 1931, p. 208,
fig. 49-50.

Pleistocene:[93] Conkling Cavern,[94] and Shelter Cave, Pyramid Peak,
Organ Mountains, Dona Ana County, New Mexico.

Order STRIGIFORMES. Owls

Family PROTOSTRIGIDAE. Protostrix[95]

Genus PROTOSTRIX Wetmore

Protostrix Wetmore, Amer. Mus. Nov., No. 680, Dec. 4, 1933, p. 3. Type,
by orig. design., *Aquila lydekkeri* Shufeldt.

Protostrix lydekkeri (Shufeldt)

Aquila lydekkeri Shufeldt, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16,
Aug. 4, 1913, p. 298.

Eocene (Bridger): Lower Cottonwood Creek, Wyoming.

Protostrix saurodosis (Wetmore)

Minerva saurodosis Wetmore, Proc. Acad. Nat. Sci. Philadelphia, vol. 73,
1921 (Apr. 6, 1922), p. 455, figs. 1-2.

Eocene (Bridger): Near Lodgepole Trail Crossing on Dry Creek,
about 10 miles from Fort Bridger, Wyoming.

---

[93] Possibly of Recent period.

[94] Type locality.

[95] *Aquila antiqua* Shufeldt, type of the genus *Minerva* Shufeldt, formerly con-
sidered an owl, proves to be a mammal. See Wetmore, Amer. Mus. Nov., No.
680, Dec. 4, 1933, pp. 1, 2.

Protostrix leptosteus (MARSH)[96]
> *Bubo leptosteus* MARSH, Amer. Journ. Sci., ser. 3, vol. 2, August 1871, p. 126.

Eocene (Bridger) : Grizzly Buttes, near Fort Bridger, Wyoming.

Protostrix mimica WETMORE
> *Protostrix mimica* WETMORE, Proc. U. S. Nat. Mus., vol. 85, Jan. 17, 1938, p. 27, figs. 4-5.

Eocene (Wasatch) : South side of Ten Mile Creek, 12 miles northwest of Worland, Wyoming.

Family TYTONIDAE. BARN OWLS

Genus TYTO Billberg

> *Tyto* BILLBERG, Syn. Faunae Scand., vol. 1, pt. 2, 1828, tab. A. Type, by monotypy, *Strix alba* SCOPOLI.

Tyto alba (SCOPOLI). **Barn Owl**
> *Strix alba* SCOPOLI, Ann. 1, Historico-Naturalis, 1769, p. 21.

Modern form reported from Pleistocene: Vero (Stratum 3), and cavern deposits near Lecanto, Florida ; Rancho La Brea, Los Angeles, and Carpinteria, California.

Family STRIGIDAE. HORNED OWLS AND ALLIES

Genus OTUS Pennant

> *Otus* PENNANT, Indian Zool., 1769, p. 3. Type, by monotypy, *Otus bakkamoena* PENNANT.

Otus asio (LINNAEUS). **Screech Owl**
> *Strix asio* LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 92.

Modern form reported from Pleistocene: Cavern deposits near Lecanto, Florida ; cave deposits of Tennessee ; Potter Creek Cave, Shasta County, Carpinteria, and Rancho La Brea, Los Angeles, California.

Otus flammeolus (KAUP). **Flammulated Screech Owl**
> *Str[ix] flammeola* "LICHT." KAUP, in JARDINE, Contr. Orn., 1852 (1853), p. 111.

Modern form reported from Pleistocene: Samwel Cave,[97] Shasta County, California.

---

[96] See Wetmore, Condor, 1937, pp. 84-85.

[97] Recorded originally as *Micropallas whitneyi*. See Miller, L. H., Trans. San Diego Soc. Nat. Hist., vol. 7, No. 19, Mar. 31, 1933, pp. 209-210.

Genus BUBO Duméril

Bubo Duméril, Zool. Analytique, 1806, p. 34. Type, by tautonymy, *Strix bubo* Linnaeus.

Bubo sinclairi Miller

Bubo sinclairi L. H. Miller, Univ. California Publ., Bull. Dep. Geol., vol. 6, No. 16, Oct. 28, 1911, p. 393, figs. 4-5.

Pleistocene: Samwel and Potter Creek[98] caves, Shasta County, California.

Bubo virginianus (Gmelin). Great Horned Owl

Strix virginiana Gmelin, Syst. Nat., vol. 1, pt. 1, 1788, p. 287.

Modern form reported from Pleistocene: Fossil Lake, Oregon; Samwel Cave, Shasta County, Carpinteria, McKittrick, and Rancho La Brea, Los Angeles, California.

Genus GLAUCIDIUM Boie

Glaucidium Boie, Isis von Oken, vol. 19, heft 10, October 1826, p. 970. Type, by monotypy, *Strix passerina* Linnaeus.

Glaucidium gnoma Wagler. Pygmy Owl

Glaucidium gnoma Wagler, Isis von Oken, vol. 25, heft 3, March 1832, p. 275.

Modern form reported from Pleistocene: Samwel Cave, Shasta County, Carpinteria, and Rancho La Brea, Los Angeles, California.

Genus SPEOTYTO Gloger

Speotyto Gloger, Hand- und Hilfsbuch, 1842 (pp. 1-450, 1841), p. 226. Type, by monotypy, *Strix cunicularia* Molina.

Speotyto cunicularia (Molina). Burrowing Owl

Strix Cunicularia Molina, Sagg. Stor. Nat. Chili, 1782, p. 263.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, Los Angeles, California.

Genus STRIX Linnaeus

Strix Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 92. Type, by tautonymy, *Strix stridula* Linnaeus = *Strix aluco* Linnaeus.

Strix varia Barton. Barred Owl

Strix varius Barton, Fragm. Nat. Hist. Pennsylvania, 1799, p. 11.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Melbourne, and cavern deposits near Lecanto, Florida.

---

[98] Type locality.

Strix brea HOWARD

Strix brea HOWARD, Condor, vol. 35, No. 2, Mar. 15, 1933, p. 66, fig. 15.

Pleistocene: Rancho La Brea, Los Angeles, California.

Genus ASIO Brisson

Asio BRISSON, Orn., 1760, vol. 1, pp. 28, 477. Type, by tautonymy, *Asio* BRISSON = *Strix otus* LINNAEUS.

Asio wilsonianus (LESSON). **Long-eared Owl**

Otus Wilsonianus LESSON, Traité d'Orn., livr. 2, May 8, 1830, p. 110.

Modern form reported from Pleistocene: Samwel Cave, Shasta County, McKittrick, and Carpinteria, California.[99]

Asio flammeus (PONTOPPIDAN). **Short-eared Owl**

Strix flammea PONTOPPIDAN, Danske Atlas, vol. 1, 1763, p. 617, pl. 25.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Genus CRYPTOGLAUX Richmond [100]

Cryptoglaux RICHMOND, Auk, vol. 18, No. 2, April 1901, p. 193. Type, by orig. design., *Strix tengmalmi* GMELIN = *Strix funerea* LINNAEUS.

Cryptoglaux acadica (GMELIN). **Saw-whet Owl**

Strix acadica GMELIN, Syst. Nat., vol. 1, pt. 1, 1788, p. 296.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Order PICIFORMES. JACAMARS, BARBETS, TOUCANS, AND WOODPECKERS

Suborder PICI. WOODPECKERS

Family PICIDAE. WOODPECKERS AND PICULETS

Subfamily PICINAE. WOODPECKERS

Genus COLAPTES Vigors

Colaptes VIGORS, Trans. Linn. Soc. London, vol. 14, pt. 3, 1825, p. 457, note. Type, by orig. design., *Cuculus auratus* LINNAEUS.

Colaptes cafer (GMELIN). **Red-shafted Flicker**

Picus cafer GMELIN, Syst. Nat., vol. 1, pt. 1, 1788, p. 431.

---

[99] According to a communication from L. H. Miller records formerly cited from Rancho La Brea are erroneous.

[100] *Cryptoglaux funerea* is recorded by Howard, Condor, 1931, p. 216, from Shelter Cave, Dona Ana County, New Mexico, in deposits that may be of late Pleistocene or early Recent age.

Modern form reported from Pleistocene : Samwel and Potter Creek caves, Shasta County, Hawver Cave, Eldorado County, McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.

Genus CEOPHLOEUS Cabanis

Ceophlocus CABANIS, Journ. für Orn., vol. 12, No. 5, May 1862, p. 176. Type, by orig. design., *Picus lineatus* LINNAEUS.

Subgenus PHLOEOTOMUS Cabanis and Heine

Phlocotomus CABANIS AND HEINE, Mus. Hein., vol. 4, pt. 2, sign. 13, July 11, 1863, p. 102. Type, by orig. design., *Picus pilcatus* LINNAEUS.

Ceophloeus pileatus (LINNAEUS). Pileated Woodpecker

Picus pileatus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 113.

Modern form reported from Pleistocene : Cave deposits of Tennessee ; Rancho La Brea, Los Angeles, California.

Genus ASYNDESMUS Coues

Asyndesmus COUES, Proc. Acad. Nat. Sci. Philadelphia, vol. 17, No. 1, January-March (June 11), 1866, p. 55. Type, by orig. design., *Picus torquatus* WILSON = *Picus lewis* GRAY.

Asyndesmus lewis (GRAY). Lewis's Woodpecker

Picus Lewis "DRAPIEZ" GRAY, Gen. Birds, vol. 3, 1849, app., p. 22.

Modern form reported from Pleistocene : Rancho La Brea, Los Angeles, California.

Order PASSERIFORMES. PERCHING BIRDS

Suborder PASSERES. SONG BIRDS

Family ALAUDIDAE. LARKS

Genus OTOCORIS Bonaparte

Otocoris BONAPARTE, Nuovi Ann. Sci. Nat. (Bologna), vol. 2, 1838, p. 407. Type, by monotypy, *Phileremos cornutus* BONAPARTE = *Alauda cornuta* WILSON = *Alauda alpestris* LINNAEUS.

Otocoris alpestris (LINNAEUS). Horned Lark

Alauda alpestris LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 166.

Modern form reported from Pleistocene : McKittrick and Rancho La Brea, Los Angeles, California.

Family PALAEOSPIZIDAE. Palaeospiza

Genus PALAEOSPIZA Allen

Palaeospiza Allen, Bull. Geol. and Geogr. Surv. Terr., vol. 4, No. 2, May 3, 1878, p. 443. Type, by monotypy, *Palaeospiza bella* Allen.

Palaeospiza bella Allen

Palaeospiza bella Allen, Bull. Geol. and Geogr. Surv. Terr., vol. 4, No. 2, May 3, 1878, p. 443, pl. 1, figs. 1-2.

Upper Miocene (Florissant lake beds): Florissant, Colorado.

Family HIRUNDINIDAE. Swallows

Genus PETROCHELIDON Cabanis

Petrochelidon Cabanis, Mus. Hein., vol. 1, October 1851, p. 47. Type, by subs. design., *Hirundo melanogaster* Swainson (Gray, 1855).

Petrochelidon albifrons (Rafinesque). **Cliff Swallow**

Hirundo albifrons Rafinesque, Kentucky Gazette, n. s., vol. 1, No. 7, Feb. 14, 1822, p. 3.

Modern form reported from Pleistocene: McKittrick, California.

Family CORVIDAE. Jays, Magpies, and Crows

Subfamily GARRULINAE. Jays and Magpies

Genus CYANOCITTA Strickland

Cyanocitta Strickland, Ann. Mag. Nat. Hist., ser. 1, vol. 15, No. 98, April 1845, p. 261. Type, by orig. design., *Corvus cristatus* Linnaeus.

Cyanocitta stelleri (Gmelin). **Steller's Jay**

Corvus stelleri Gmelin, Syst. Nat., vol. 1, pt. 1, 1788, p. 370.

Modern form reported from Pleistocene: Samwel Cave, Shasta County, Hawver Cave, Eldorado County, Rancho La Brea, Los Angeles, and Carpinteria, California.

Genus APHELOCOMA Cabanis

Aphelocoma Cabanis, Mus. Hein., vol. 1, sign. 28, Oct. 15, 1851, p. 221 (note). Type, by subs. design., *Garrulus californicus* Vigors (Baird, 1858).

Subgenus APHELOCOMA Cabanis

Aphelocoma californica (Vigors). **California Jay**

Garrulus Californicus Vigors, in Zool. Beechey's Voy., 1839, p. 21, pl. 5.

Modern form reported from Pleistocene: McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.

Genus PICA Brisson

Pica Brisson, Orn., 1760, vol. 1, p. 30; vol. 2, p. 35. Type, by tautonymy, *Pica* Brisson = *Corvus pica* Linnaeus.

Pica nutallii (Audubon). Yellow-billed Magpie

Corvus nutallii Audubon, Birds Amer. (folio), vol. 4, 1836 (1837?), pl. 362, fig. 1.

Modern form reported from Pleistocene: McKittrick, Carpinteria, and Rancho La Brea, Los Angeles, California.

Subfamily CORVINAE. Crows and Ravens

Genus CORVUS Linnaeus

Corvus Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 105. Type, by subs. design., *Corvus corax* Linnaeus (Gray, 1840).

Corvus corax Linnaeus. Raven

Corvus corax Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 105.

Modern form reported from Pleistocene: Hawver Cave, Eldorado County, Carpinteria, McKittrick, Rancho La Brea, Los Angeles, and Upper San Pedro, near Playa del Rey, California.

Corvus cryptoleucus Couch. White-necked Raven

Corvus cryptoleucus Couch, Proc. Acad. Nat. Sci. Philadelphia, vol. 7, No. 2, May 20, 1854, p. 66.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, Los Angeles, California.

Corvus shufeldti Sharpe

Corvus shufeldti Sharpe, Hand-list Gen. Spec. Birds, vol. 5, 1909, p. 599.

Pleistocene: Fossil Lake, Oregon.

Corvus brachyrhynchos Brehm. Crow

Corvus brachyrhynchos C. L. Brehm, Beitr. Vögelkunde, vol. 2, 1822, p. 56.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida; Potter Creek Cave, Shasta County, Carpinteria and Rancho La Brea, Los Angeles, California.

Corvus caurinus Baird. Northwestern Crow [1]

Corvus caurinus Baird, in Baird, Cassin, and Lawrence, Rep. Expl. and Surv. R. R. Pac., vol. 9, 1858, pp. xiii, 559, 569.

Modern form reported from Pleistocene: Carpinteria, and Rancho La Brea, Los Angeles, California.

[1] Although currently listed as a subspecies of *Corvus brachyrhynchos,* this bird in my opinion is not of that species, being more closely allied to the fish crow, *Corvus ossifragus.*

Corvus ossifragus WILSON. **Fish Crow**

Corvus ossifragus WILSON, Amer. Orn., vol. 5, 1812, p. 27, pl. 37, fig. 2.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Genus CYANOCEPHALUS Bonaparte

Cyanocephalus BONAPARTE, Osserv. Stato Zool. Eur., 1842, p. 17. Type, by monotypy, *Gymnorhinus cyanocephalus* WIED.

Cyanocephalus cyanocephalus (WIED). **Piñon Jay**

Gymnorhinus cyanocephalus WIED, Reise Nord-Amer., vol. 2, 1841, p. 22.

Modern form reported from Pleistocene: Conkling Cavern, Pyramid Peak, Organ Mountains, Dona Ana County, New Mexico.

Family SITTIDAE. NUTHATCHES

Subfamily SITTINAE. TYPICAL NUTHATCHES

Genus SITTA Linnaeus

Sitta LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 115. Type, by monotypy, *Sitta europaea* LINNAEUS.

Sitta canadensis LINNAEUS. **Red-breasted Nuthatch**

Sitta canadensis LINNAEUS, Syst. Nat., 12th ed., vol. 1, 1766, p. 177.

Modern form reported from Pleistocene: Carpinteria, California.

Sitta pygmaea VIGORS. **Pygmy Nuthatch**

Sitta pygmaea VIGORS, in Zool. Beechey's Voy., 1839, p. 25, pl. 4, fig. 2.

Modern form reported from Pleistocene: Carpinteria, California.

Family CHAMAEIDAE. WREN-TITS

Genus CHAMAEA Gambel

Chamaea GAMBEL, Proc. Acad. Nat. Sci. Philadelphia, vol. 3, No. 7, January-February (May 7), 1847, p. 154. Type, by orig. design., *Parus fasciatus* GAMBEL.

Chamaea fasciata (GAMBEL). **Wren-tit**

Parus fasciatus GAMBEL, Proc. Acad. Nat. Sci. Philadelphia, vol. 2, No. 10, July-August (Dec. 5), 1845, p. 265.

Modern form reported from Pleistocene: Carpinteria, California.

Family MIMIDAE. Thrashers and Mockingbirds

Genus TOXOSTOMA Wagler

Toxostoma WAGLER, Isis von OKEN, vol. 24, heft 5 (May) 1831, col. 528. Type, by monotypy, *Toxostoma vetula* WAGLER = *Orpheus curvirostris* SWAINSON.

Toxostoma bendirei (COUES). Bendire's Thrasher

Harporhynchus bendirei COUES, Amer. Nat., vol. 7, No. 6, June 1873, p. 330.

Modern form reported from Pleistocene: McKittrick, California.

Toxostoma redivivum (GAMBEL). California Thrasher

Harpes rediviva GAMBEL, Proc. Acad. Nat. Sci. Philadelphia, vol. 2, No. 10, July-August (Dec. 5), 1845, p. 264.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Genus OREOSCOPTES Baird

Oreoscoptes BAIRD, in BAIRD, CASSIN, AND LAWRENCE, Rep. Expl. Surv. R. R. Pac., vol. 9, 1858, pp. xix, xxxv. Type, by monotypy, *Orpheus montanus* TOWNSEND.

Oreoscoptes montanus (TOWNSEND). Sage Thrasher

Orpheus montanus TOWNSEND, Journ. Acad. Nat. Sci. Philadelphia, vol. 7, pt. 2, Nov. 21, 1837, p. 192.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, California.

Family TURDIDAE. Thrushes

Genus TURDUS Linnaeus

Turdus LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 168. Type, by subs. design., *Turdus merula* LINNAEUS (Selby, 1825).

Turdus migratorius LINNAEUS. Robin

Turdus migratorius LINNAEUS, Syst. Nat., 12th ed., vol. 1, 1766, p. 292.

Modern form reported from Pleistocene: Carpinteria, California.

Genus SIALIA Swainson

Sialia SWAINSON, Phil. Mag., n. s., vol. 1, No. 5, May 1827, p. 369. Type, by monotypy, *Sialia azurea* SWAINSON = *Motacilla sialis* LINNAEUS.

Sialia mexicana SWAINSON. Mexican Bluebird

Sialia mexicana SWAINSON, Fauna Bor.-Amer., vol. 2, 1831, p. 202.

Modern form reported from Pleistocene: Carpinteria, California.

Family BOMBYCILLIDAE. Waxwings

Genus BOMBYCILLA Vieillot

Bombycilla Vieillot, Oiseaux Amér. Sept., vol. 1, 1807 (1808), p. 88. Type, by monotypy, *Bombycilla cedrorum* Vieillot.

Bombycilla cedrorum Vieillot. Cedar Waxwing

Bombycilla cedrorum Vieillot, Oiseaux Amér. Sept., vol. 1, 1807 (1808), p. 88, pl. 57.

Modern form reported from Pleistocene: Carpinteria and Rancho La Brea, Los Angeles, California.

Family LANIIDAE. Shrikes

Subfamily LANIINAE. Shrikes

Genus LANIUS Linnaeus

Lanius Linnaeus, Syst. Nat., 10th ed., vol. 1, 1758, p. 93. Type, by subs. design., *Lanius excubitor* Linnaeus (Swainson, 1824).

Lanius ludovicianus Liinnaeus. Loggerhead Shrike

Lanius ludovicianus Linnaeus, Syst. Nat., 12th ed., vol. 1, 1766, p. 134.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, Los Angeles, California.

Family ICTERIDAE. Blackbirds and Troupials

Genus STURNELLA Vieillot

Sturnella Vieillot, Analyse, 1816, p. 34. Type, by monotypy, Stourne, ou Merle à fer-à-cheval Buffon = *Alauda magna* Linnaeus.

Sturnella neglecta Audubon. Western Meadowlark

Sturnella neglecta Audubon, Birds Amer., octavo ed., vol. 7, 1844, p. 339, pl. 489.

Modern form reported from Pleistocene: Carpinteria, Rancho La Brea, Los Angeles, and Upper San Pedro, San Pedro, California.

Genus AGELAIUS Vieillot

Agelaius Vieillot, Analyse, 1816, p. 33. Type, by subs. design., Troupiale commandeur Buffon = *Oriolus phoeniceus* Linnaeus (Gray, 1840).

Agelaius phoeniceus (Linnaeus). Red-winged Blackbird

Oriolus phoeniceus Linnaeus, Syst. Nat., 12th ed., vol. 1, 1766, p. 161.

Modern form reported from Pleistocene: Seminole Field, Pinellas County, Florida.

Genus EUPHAGUS Cassin [2]

Euphagus CASSIN, Proc. Acad. Nat. Sci. Philadelphia, vol. 18, No. 5, November-December, 1866 (July 20, 1867), p. 413. Type, by monotypy, *Psarocolius cyanocephalus* WAGLER.

Euphagus affinis (SHUFELDT)

Scolecophagus affinis SHUFELDT, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 9, sig. 53, Oct. 20, 1892, p. 418, pl. 15, fig. 10.

Pleistocene : Fossil Lake, Oregon.

Euphagus magnirostris MILLER

Euphagus magnirostris A. H. MILLER, Univ. California Publ., Bull. Dep. Geol. Sci., vol. 19, No. 1, Dec. 21, 1929, p. 14, pl. 1, figs. *f, h*.

Pleistocene : Rancho La Brea, Los Angeles, California.

Genus CASSIDIX Lesson

Cassidix LESSON, Traité d'Orn., livr. 6, Feb. 1, 1831, p. 433. Type, by subs. design., *Cassidix mexicanus* LESSON = *Corvus Mexicanus* GMELIN (Gray, 1840).

Cassidix mexicanus (GMELIN). Great-tailed Grackle

Corvus mexicanus GMELIN, Syst. Nat., vol. 1, pt. 1, 1788, p. 375.

Modern form reported from Pleistocene : Seminole Field, Pinellas County, Florida.

Genus QUISCALUS Vieillot

Quiscalus VIEILLOT, Analyse, 1816, p. 36. Type, by subs. design., *Gracula quiscula* LINNAEUS (Gray, 1840).

Quiscalus quiscula (LINNAEUS). Purple Grackle

Gracula quiscula LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 109.

Modern form reported from Pleistocene : Seminole Field, Pinellas County, Florida.

Genus PYELORHAMPHUS Miller

Pyelorhamphus A. H. MILLER, Auk, vol. 49, No. 1, January 1932, p. 39. Type, by orig. design., *Pyelorhamphus molothroides* MILLER.

Pyelorhamphus molothroides MILLER

Pyelorhamphus molothroides ,A. H. MILLER, Auk, vol. 49, No. 1, January 1932, p. 39, pl. 4.

---

[2] *Euphagus cyanocephalus* reported by L. H. Miller from the Pleistocene of Hawver Cave, Eldorado County, California (Univ. California Publ. Geol., vol. 6, Oct. 28, 1911, pp. 399, 400), was subsequently questioned by the same author (Condor, 1921, p. 130). In recent correspondence A. H. Miller writes that he has examined the material reported on from this cave and does not find this species represented. It is therefore omitted from the list.

Quaternary (Pleistocene?) :[3] Shelter Cave, Pyramid Peak, Organ Mountains, Dona Ana County, New Mexico.

Family FRINGILLIDAE. GROSBEAKS, FINCHES, AND BUNTINGS

Subfamily CARDUELINAE. PURPLE FINCHES, GOLDFINCHES, AND ALLIES

Genus CARPODACUS Kaup

Carpodacus KAUP, Skizz. Entw.-Gesch. Eur. Thierw., 1829, p. 161. Type, by subs. design., *Loxia rosea* PALLAS (Gray, 1842).

Carpodacus mexicanus (MÜLLER). House Finch

Fringilla mexicana MÜLLER, Syst. Nat., Suppl., 1776, p. 165.

Modern form reported from Pleistocene: McKittrick, California.

Genus SPINUS Koch

Spinus KOCH, Syst. Baier. Zool., 1816, p. 233. Type, by tautonymy, *Fringilla spinus* LINNAEUS.

Spinus pinus (WILSON). Pine Siskin

Fringilla pinus WILSON, Amer. Orn., vol. 2, 1810, p. 133, pl. 17, fig. 1.

Modern form reported from Pleistocene: Carpinteria, and Rancho La Brea, Los Angeles, California.

Spinus tristis (LINNAEUS). Goldfinch

Fringilla tristis LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 181.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Genus LOXIA Linnaeus

Loxia LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 171. Type, by subs. design., *Loxia curvirostra* LINNAEUS (Gray, 1840).

Loxia curvirostra LINNAEUS. Red Crossbill

Loxia Curvirostra LINNAEUS, Syst. Nat., 10th ed., vol. 1, 1758, p. 171.

Modern form reported from Pleistocene: Carpinteria, California.

---

[3] The deposits in which this extinct species was found are possibly Recent.

Subfamily EMBERIZINAE. BUNTINGS

Genus PALAEOSTRUTHUS Wetmore

Palaeostruthus WETMORE, Bull. Mus. Comp. Zoöl., vol. 67, May 1925, p. 192. Type, by orig. design., *Palaeospiza hatcheri* SHUFELDT.

Palaeostruthus hatcheri (SHUFELDT)

Palaeospiza hatcheri SHUFELDT, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 16, Aug. 4, 1913, p. 301, pl. 55, fig. 28.

Miocene: Near Long Island, Kansas.

Genus PIPILO Vieillot

Pipilo VIEILLOT, Analyse, 1816, p. 32. Type, by monotypy, Pinson aux yeux rouges BUFFON = *Fringilla erythrophthalma* LINNAEUS.

Pipilo maculatus SWAINSON. Spotted Towhee

Pipilo maculata SWAINSON, Phil. Mag., n. s., vol. 1, 1827, p. 434.

Modern form reported from Pleistocene: Carpinteria, California.

Pipilo fuscus SWAINSON. Brown Towhee

Pipilo fusca SWAINSON, Phil. Mag., n. s., vol. 1, 1827, p. 434.

Modern form reported from Pleistocene: Carpinteria, California.

Genus AMPHISPIZA Coues

Amphispiza COUES, Birds Northwest, 1874, p. 234. Type, by orig. design., *Emberiza bilineata* CASSIN.

Amphispiza bilineata (CASSIN). Black-throated Sparrow

Emberiza bilineata CASSIN, Proc. Acad. Nat. Sci. Philadelphia, vol. 5, No. 5, September-October (Dec. 7), 1850, p. 104, pl. 3.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Amphispiza belli (CASSIN). Bell's Sparrow

Emberiza Belli CASSIN, Proc. Acad. Nat. Sci. Philadelphia, vol. 5, No. 5, September-October (Dec. 7), 1850, p. 104, pl. 4.

Modern form reported from Pleistocene: McKittrick and Rancho La Brea, Los Angeles, California.

Genus SPIZELLA Bonaparte

Spizella BONAPARTE, Giornale Arcadico, vol. 52, 1832, p. 205. Type, by monotypy, *Fringilla pusilla* WILSON.

Spizella passerina (BECHSTEIN), Chipping Sparrow

Fringilla passerina BECHSTEIN, in LATHAM, Allgem. Ueb. Vögel, vol. 3, pt. 2, 1798, p. 544, pl. 120, fig. 1.

Modern form reported from Pleistocene: Rancho La Brea, Los Angeles, California.

Genus PASSERELLA Swainson

Passerella SWAINSON, Class. Birds, vol. 2, July 1, 1837, p. 288. Type, by
monotypy, *Fringilla iliaca* MERREM.

Passerella iliaca (MERREM). Fox Sparrow

Fringilla iliaca MERREM, Avium Rar. Icones et Descrip., vol. 2, 1786, p. 37,
pl. 10.

Modern form reported from Pleistocene: Carpinteria, California.

INCERTAE SEDIS

Genus CIMOLOPTERYX Marsh [4]

Cimolopteryx MARSH, Amer. Journ. Sci., ser. 3, vol. 38, 1889, p. 83, foot-
note. Type, by monotypy, *Cimolopteryx rarus* MARSH.

Cimolopteryx rarus MARSH

Cimolopteryx rarus MARSH, Amer. Journ. Sci., ser. 3, vol. 38, July 1889,
p. 83, footnote.

Upper Cretaceous (Lance): Niobrara County, Wyoming.

Cimolopteryx retusus MARSH

Cimolopteryx retusus MARSH, Amer. Journ. Sci., ser. 3, vol. 44, August 1892,
p. 175.

Upper Cretaceous (Lance): Niobrara County, Wyoming.

Genus EOPTERYX Meyer

Eopteryx MEYER, Ber. Senckenberg. Nat. Ges. Frankfurt am Main, 1887,
p. 14. Type, by monotypy, *Eopteryx mississippiensis* MEYER.

Eopteryx mississippiensis MEYER [5]

Eopteryx mississippiensis MEYER, Ber. Senckenberg. Nat. Ges. Frankfurt am
Main, 1887, p. 14, pl. 2, figs. *22a-22c.*

Eocene: Jackson, Mississippi.

(Genus uncertain)

Falco falconellus SHUFELDT [6]

Falco falconella SHUFELDT, Trans. Connecticut Acad. Arts Sci., vol. 19,
February 1915, p. 40, pl. 15, figs. 139-143.

Eocene (Bridger): Dry Creek?, Wyoming.

---

[4] Lambrecht, Handb. Palaeorn., 1933, pp. 586-587, lists this genus at the end
of the Ichthyornithiformes. He suggests that the two species belong in separate
genera, possibly in different families. See also Shufeldt, Trans. Connecticut
Acad. Arts Sci., vol. 19, February 1915, pp. 11, 12, and 76.

[5] Described from a fragmentary vertebra.

[6] Not a falcon; relationships doubtful. See, Wetmore, A., Proc. U. S. Nat.
Mus., vol. 84, Nov. 3, 1936, pp. 77-78.

Genus FONTINALIS Lesquereux

Fontinalis Lesquereux, Rep. U. S. Geol. Surv. Terr., vol. 8, 1883, p. 135. Type, by monotypy, *Fontinalis pristina* Lesquereux.

Fontinalis pristina Lesquereux [7]

Fontinalis pristina Lesquereux, Rep. U. S. Geol. Surv. Terr., vol. 8, 1883, p. 135, pl. 21, fig. 9.

Upper Miocene (Florissant lake beds) : Florissant, Colorado.

Genus HEBE Shufeldt

Hebe Shufeldt, Journ. Geol., vol. 21, October-November (Nov. 1), 1913, p. 644. Type, by monotypy, *Hebe schucherti* Shufeldt.

Hebe schucherti Shufeldt [8]

Hebe schucherti Shufeldt, Journ. Geol., vol. 21, October-November (Nov. 1), 1913, p. 644, fig. 10, *a, b.*

Eocene : [9] Five miles west of Green River, Wyoming.

Genus IGNOTORNIS Mehl

Ignotornis Mehl, Amer. Journ. Sci., ser. 5, vol. 21, May 1931, p. 443. Type, by monotypy, *Ignotornis mcconnelli* Mehl.

Ignotornis mcconnelli Mehl [10]

Ignotornis mcconnelli Mehl, Amer. Journ. Sci., ser. 5, vol. 21, May 1931, p. 444, fig. 1.

Cretaceous (Dakota Sandstone) : about $1\frac{1}{2}$ miles northwest of Golden, Colorado.

Genus LAOPTERYX Marsh

Laopteryx Marsh, Amer. Journ. Sci., ser. 3, vol. 21, April 1881, p. 341. Type, by monotypy, *Laopteryx priscus* Marsh.

Laopteryx priscus Marsh [11]

Laopteryx priscus Marsh, Amer. Journ. Sci., ser. 3, vol. 21, April 1881, p. 341.

---

[7] Type a fragment of a fossil feather, described originally as a species of moss. See Knowlton, Proc. U. S. Nat. Mus., vol. 51, Nov. 24, 1916, p. 245, and Wetmore, Bull. Mus. Comp. Zoöl., vol. 67, May 1925, p. 184.

[8] Said to be a passeriform bird with four notches in the posterior border of the sternum; of uncertain affinity. *Hebe* Shufeldt 1913, is preoccupied by *Hebe* Risso 1826 (applied to a genus of crustaceans) so that should the form here under consideration be definitely identified it may require a new generic appellation. There is no necessity for action at this time in view of its uncertain relationships.

[9] From data furnished by Dr. M. R. Thorpe, of the Peabody Museum, Yale University.

[10] Described from fossil impressions of four-toed footprints, apparently with webs connecting the three anterior toes.

[11] J. D. Dana, Amer. Journ. Sci., ser. 5, vol. 12, July 1926, pp. 3, 4, considers the avian affinity of this supposed species as not definitely certain.

Upper Jurassic (Morrison): Quarry 9, Como Bluff, southern Wyoming.

Genus LAORNIS Marsh

Laornis MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 206. Type, by monotypy, *Laornis edvardsianus* MARSH.

Laornis edvardsianus MARSH [12]

Laornis edvardsianus MARSH, Amer. Journ. Sci., ser. 2, vol. 49, March 1870, p. 206.

Eocene (Hornerstown): near Birmingham, New Jersey.

Genus PALAEONORNIS Emmons

Palaeonornis EMMONS, Amer. Geol., pt. 6, 1857, p. 148. Type, by monotypy, *Palaeonornis struthionoides* EMMONS.

Palaeonornis struthionoides EMMONS [13]

Palaeonornis Struthionoides EMMONS, Amer. Geol., pt. 6, 1857, p. 148, fig. 114.

? Triassic: Anson County, North Carolina.

Genus UINTORNIS Marsh

Uintornis MARSH, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 259. Type, by monotypy, *Uintornis lucaris* MARSH.

Uintornis lucaris MARSH [14]

Uintornis lucaris MARSH, Amer. Journ. Sci., ser. 3, vol. 4, October 1872, p. 259.

Eocene (Bridger): near Henry's Fork, Wyoming.

Genus YALAVIS Shufeldt

Yalavis SHUFELDT, Journ. Geol., vol. 21, October-November (Nov. 1), 1913, p. 649. Type, by monotypy, *Yalavis tenuipes* SHUFELDT.

Yalavis tenuipes SHUFELDT [15]

Yalavis tenuipes SHUFELDT, Journ. Geol., vol. 21, October-November (Nov. 1), 1913, p. 649, figs. 11c and 12c.

Geologic age and locality of occurrence not known.

---

[12] Doutbfully related to Anseriformes. Lambrecht, Handb. Palaeorn., 1933, pp. 526-527, has placed it uncertainly after the Aramidae.

[13] Affinity doubtful: possibly not avian.

[14] According to Shufeldt, Trans. Connecticut Acad. Arts Sci., vol. 19, February 1915, pp. 50-52, 77, pl. 6, fig. 42, this species is of uncertain affinity, and is not a woodpecker as suggested by Marsh.

[15] Said in the original description to be a passeriform bird of uncertain affinity.

THE 11-YEAR AND 27-DAY SOLAR PERIODS IN METEOROLOGY

BY

H. HELM CLAYTON

(PUBLICATION 3589)

THE 11-YEAR AND 27-DAY SOLAR PERIODS IN METEOROLOGY

BY
H. HELM CLAYTON

(Publication 3589)

THE 11-YEAR AND 27-DAY SOLAR PERIODS
IN METEOROLOGY

By H. HELM CLAYTON

Soon after the discovery of the 11-year period in sunspots, about 1850, the question was raised as to a possible relation between solar changes and the earth's weather. It was supposed that if these spot changes produce any change on the earth, its influence would be felt over the entire earth in the same manner. If the sun became warmer the entire earth would become warmer; if the sun became colder the entire earth would become colder. The exhaustive research of Köppen seemed to confirm this view. Using all available published records, which were mostly from land areas in middle and low latitudes, Köppen [1] found that the mean temperature of the earth was slightly lower at sunspot maximum than at sunspot minimum. When measurements at the Smithsonian Astrophysical Observatory indicated a greater heat radiation from the sun at sunspot maximum than at sunspot minimum, it was thought to be an anomaly, and even now writers frequently refer to the anomaly of a hotter sun and a colder earth.

However, other researches indicate that the relation of solar changes to terrestrial weather is far more complex than this simple theory suggests. Blanford [2] showed that at sunspot maxima there were opposing oscillations in pressure between Russia and India, and Lockyer [3] found opposing pressure oscillations between the region of the Indian Ocean and a region centered around Santiago, Chile. Hildebandsson and Weickmann added many examples of these opposing oscillations that exist in temperature and rainfall as well as in pressure, although they did not connect them with solar changes. That these opposing oscillations exist throughout the earth becomes evident to

---

[1] Köppen, W., Lufttemperaturen, Sonnenflecken und Vulkan ausbrücke. Meteor. Zeitschr., July 1914, pp. 305-308.

[2] Blanford, H. F., On the barometric see saw between Russia and India in the sun-spot cycle. Nature, vol. 20, pp. 477-482, Mar. 18, 1880.

[3] Lockyer, Norman, Simultaneous solar and terrestrial changes. Nature, vol. 69, pp. 351-357, 1902; Lockyer, William, A world-wide barometric see-saw. Nature, vol. 70, p. 177, June 23, 1904.

anyone who makes a plot of pressure and temperature changes over any large portion of the earth's surface. Figure 1 shows a plot of the monthly departures from normal temperature at Helena, Mont., and at New Haven, Conn., during the 10 years from 1930-1939, covering

MONTHLY DEPARTURES FROM NORMAL TEMPERATURES
AND THE SUN SPOT CURVE, 1930-1939
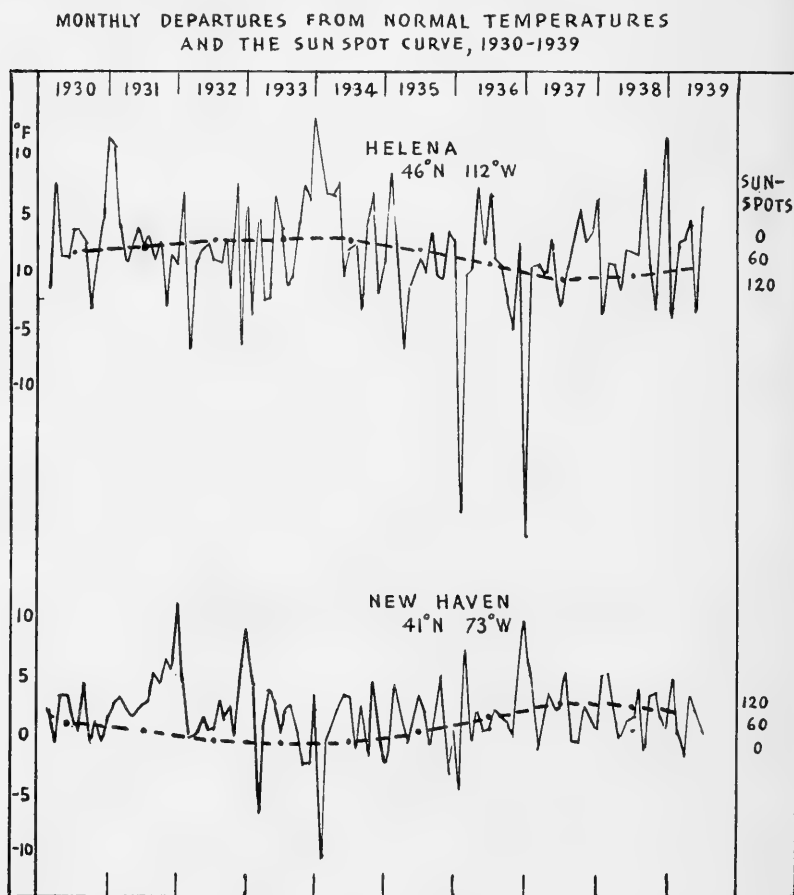
Fig. 1.—Monthly departures from normal temperature in western and eastern parts of United States compared with annual sunspot numbers.

most of the last sunspot period. A curve connecting the annual relative sunspot numbers is drawn through this plot of monthly temperature departures, but the numbers are inverted in the upper curve.

The curve for Helena fairly represents the temperature changes that took place between the Mississippi Valley and the Pacific Coast during the decade, and the curve for New Haven fairly represents the changes which took place in the Atlantic Coast States from

Maine to Florida. The curve for Helena shows that the greatest excess of temperature occurred at sunspot minimum in 1934 and the greatest cold occurred at sunspot maximum in 1937, whereas exactly opposite conditions prevailed in New Haven—the greatest cold occurred in 1934, and the greatest excess of temperature above normal after 1932 occurred in 1937. The mean difference in temperature between the years ending in August 1934 and 1937 at Helena was 6.5° F. and between the same years at New Haven was 2.3° F. with signs reversed. That is, there was a change of about 9 degrees in the temperature gradient between the two stations in the interval from the sunspot minimum of 1934 and the sunspot maximum of 1937. The extremely cold month, January 1937, shows a mean temperature difference between Helena and New Haven nearly 30° F. greater than the normal difference.

The early discoverers of these seesaw oscillations thought that the centers of oscillation were permanent in position. It followed that the sunspot effect, if any, would remain alike at each place and repeat itself in the same phase with each recurrent sunspot period. My investigations have disclosed that this conclusion is not justified.

In the American Meteorological Journal of 1884, vol. 1, pp. 130 and 528, I pointed out that an opposing oscillation of pressure and temperature in the United States having a period of about 25 months did not remain fixed in positions, but the centers of oscillation had a slow progressive motion. Later investigations have shown that this progressive motion is true for oscillations of all lengths, although the centers appear to re-form in certain favored locations.

Oscillations of pressure connected with the sunspot period show this progressive motion clearly.

In my recent paper on the sunspot period [4] it was shown that areas of excess pressure observed over the oceans in middle latitudes at the time of moderate solar activity move northward as solar activity increases. As a consequence, the phase of the sunspot period in atmospheric pressure inverts in all latitudes. (See fig. 2.) In 1906, with moderate solar activity the maximum excess of pressure was near latitude 40° N.; in 1893, with higher solar activity, it was near latitude 50° N.; and in 1917, with high solar activity, it was about latitude 60° N. The higher the solar activity the higher the latitude in which the areas of excess pressures are found. There is evidence that this is true both north and south of the Equator.

[4] Clayton, H. Helm, The sunspot period, Smithsonian Misc. Coll., vol. 98, No. 2, 1939.
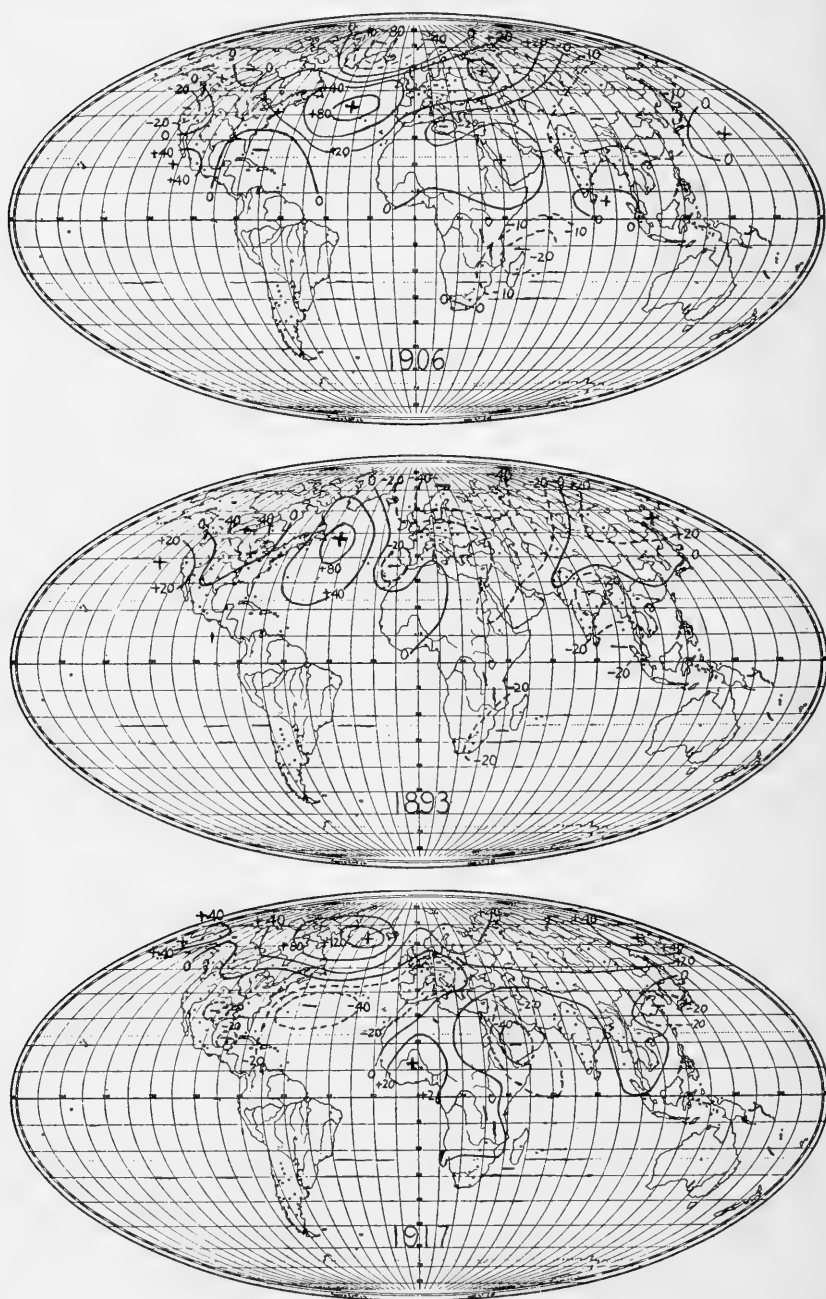
Fig. 2.—Atmospheric pressure at maxima of sunspots, 1906, 1893, 1917. (Unit 0.01 mm.)

Figure 3 shows oscillations of the annual means of pressure in the Tropics freed from a long-time trend. It also shows 5-year averages by a dotted curve. These curves are compared with the inverted sunspot curve. It is seen from the diagram that the 5-year means of pressure from 1890 to 1925 in the Tropics oscillated inversely to the sunspot curve. However, there is evidence that even in the Tropics the sunspot influence is intermittent and occasionally inverts in phase. Oscillations in the level of Lake Victoria Nyanza, situated in central Africa directly under the Equator, oscillated in phase with the sunspots from about 1890 to 1923.[5] After that time a tendency to invert in phase showed itself. Broken observations about 1870
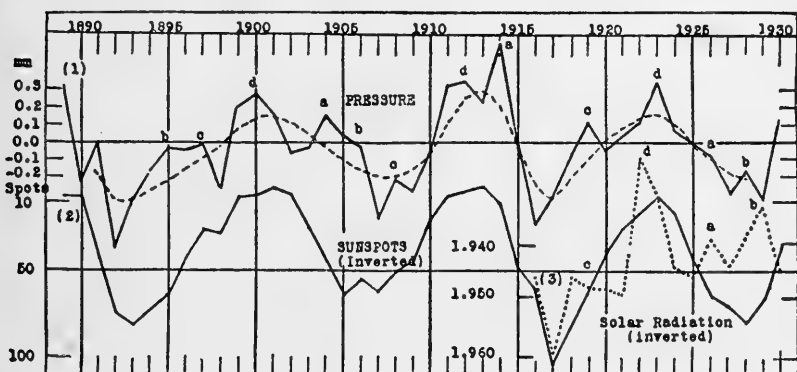
FIG. 3.—Comparison of mean pressures in the Tropics with sunspots and solar radiation. (1) Mean annual pressures at Quixeramobim and Antananarivo, corrected for trend. (2) Mean annual number of sunspots, inverted. (3) Mean annual values of solar radiation, in calories per minute, inverted.

also indicate a reversal of phase in regard to the sunspot period about 1870. Sydney M. Wood has recently shown [6] that low levels of the Nile show oscillations similar to the variations of Lake Victoria Nyanza (see fig. 4). These variations were probably produced mainly by an increased rainfall in the tropical belt which my investigations show existed during the same period.[7] The variation in evaporation was a contributory influence.

With very high sunspot activity at the time of sunspot maxima an excess of pressure over normal (baroplion) is found at stations

[5] Brooks, C. E. P., Variations in the levels of the central African lakes, Victoria and Albert, Geophys. Mem., No. 20, London, 1923.

[6] Wood, Sydney M., 31st Ann. Rep. Engineering Soc. Wisconsin, Inc., p. 102, 1939.

[7] Clayton, H. H., World weather, p. 264. Macmillan Co., New York, 1923.
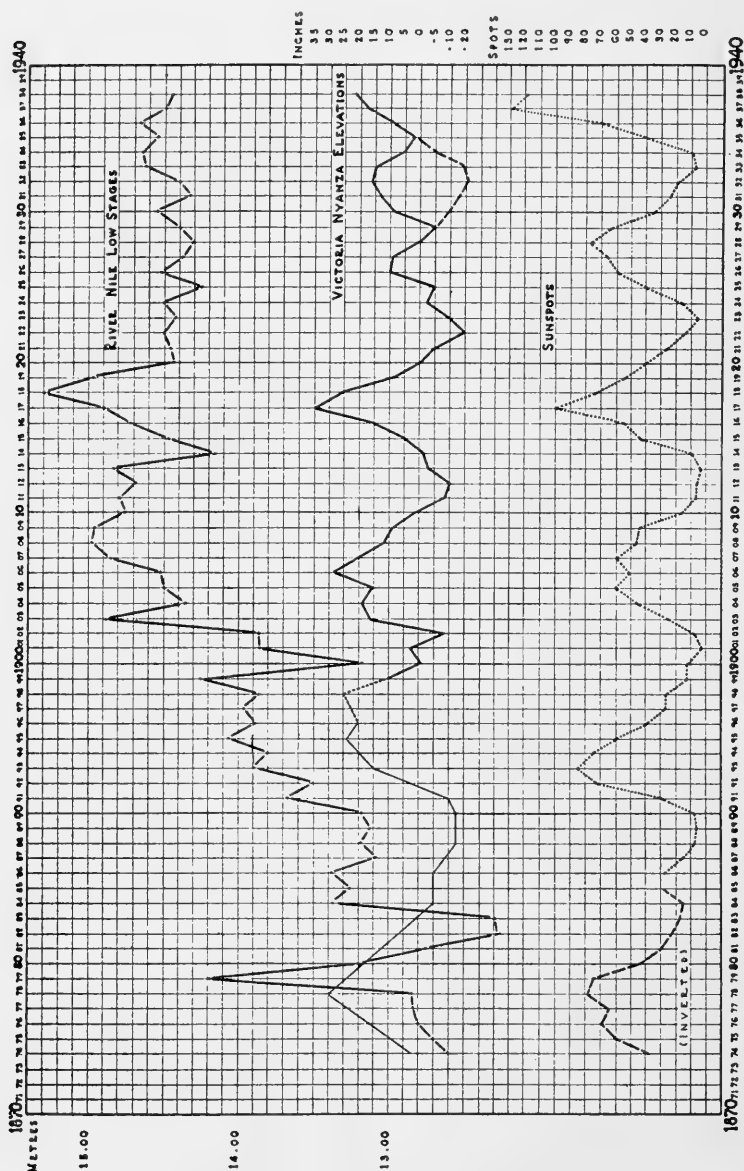
RIVER NILE LOW STAGES, WITH THE VICTORIA NYANZA ELEVATIONS & SUNSPOT FREQUENCIES 1874-1938

FIG. 4.—A reverse relationship between Nyanza and sunspots took place in the period near 1878 (shown with spots in reverse) and following 1929 (Nyanza curve shown in reverse). Illustration in reverse was made at the suggestion of H. H. Clayton.—(After Sydney Makepeace Wood.)

in both hemispheres in high latitudes, whereas with moderate sun-
spot activity at the time of sunspot maximum the excess of pressure
is found near 40° latitude.[8] When the excess of pressure is found
in high latitudes, as in 1870, 1917, and 1937, not only is there a
widening of the belt of low pressure near the Poles, but centers of
lower than normal pressure (baromions) develop about latitude 30°
north and south of the Equator. As a result, indraught of air
toward the Equator is lessened or reversed.

During the last century each alternate period of solar activity
has been greater than the intermediate one, so that a period of 22
to 23 years was engendered which has been investigated by Dr.
C. G. Abbot.[9] It is evident, if this finding is correct, that the centers
of excess and defect of pressure are in constant movement and do
not repeat themselves in the same manner at the same place at each
sunspot maximum unless the solar intensities at successive sunspot
maxima are nearly the same, and that rarely happens.

Such moving centers of oscillation have been found by me for
every period of solar activity so far investigated, even to periods
of only a few days in length. In addition Professor Turner, of
Oxford, Dr. Abbot, Secretary of the Smithsonian Institution, and
K. F. Wasserfalls, of Bergen, Norway, have advocated changes of
phase in meteorological periods; but apparently the idea seems fan-
tastic to most meteorologists, who either believe there are no meteor-
ological periods or else are seeking periods that do not change in
phase and intensity.

However, there are certain general regions where during the sun-
spot period areas of excess or defect of pressure tend to form. As
shown in the preceding pages, areas of excess pressure tend to form
in high latitudes with high solar activity. They tend to form over
continents in winter and over oceans in summer, thus reversing the
effect with the seasons.[10]

By dealing only with the summer rainfall (June—August), W. A.
Thorn, of the Canadian Meteorological Office, was able to show a
relation of the Toronto rainfall to the sunspot variations (see fig. 5)
extending from 1848 to 1931.

Recently I have had under way investigations in regard to the
period of solar rotation of about 27 days. Spot groups not infre-

---

[8] Clayton, H. H. World weather and solar activity, Smithsonian Misc. Coll.,
vol. 89, No. 15, pp. 10-11, 1934.

[9] Abbot, C. G., Solar radiation and weather studies, Smithsonian Misc. Coll.,
vol. 94, No. 10, 1935.

[10] Clayton, H. H., World weather, p. 303. Macmillan Co., New York, 1923.

quently form in some definite longitude on the sun and continue to
return opposite the earth for many solar rotations. Oscillations in
the number of sunspots approximating a period of 27 days were
observed in the latter part of 1936 and in the first half of 1937 and
have been under investigation in regard to their meteorological rela-
tions. For this purpose, some pressure data prepared by Jean Gal-
lenne for publication in World Weather Records were used. Owing
to a gift from John A. Roebling to the Smithsonian Institution, it
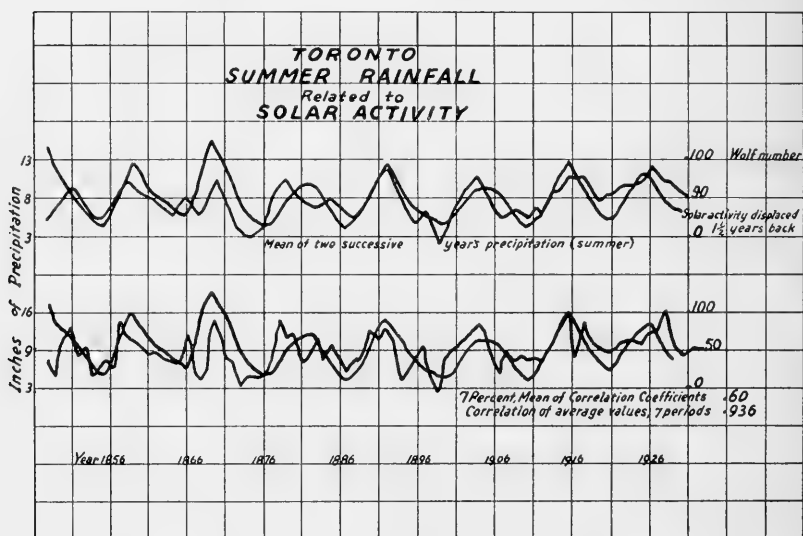
FIG. 5.—Comparison of summer rainfall at Toronto with sunspot numbers. In
the upper curve the monthly rainfalls are smoothed by the formula $\dfrac{a + 2b + c}{4}$.
In the lower curve the unsmoothed rainfalls are given.—(After W. A. Thorn.)

has been possible to obtain the pressure from daily weather maps
at the intersections of each 10° of latitude and longitude over most
of the northern hemisphere. These barometric pressures when
plotted in curves are compared with sunspots plotted in the same
manner as shown in figures 6 and 7. The continuous curves connect
day to day pressures, and the dotted curves show the daily sunspot
numbers as prepared at Zurich. During the winter and spring there
is an evident direct relation between the sunspots and pressure in
the North Pacific and North Atlantic Oceans near latitude 60°. At
30° latitude the relation tends to be inverted. This relation is of the
same nature as that found for the sunspot period of 11 years.
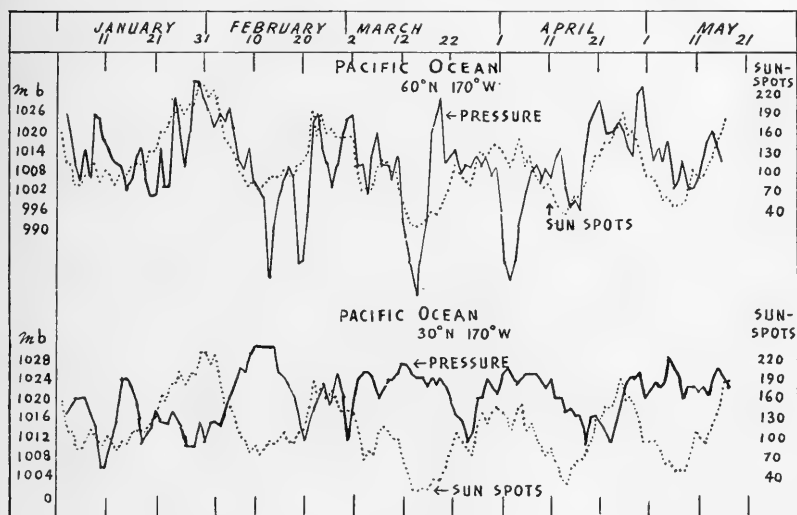
Fig. 6.—Daily sunspot numbers compared with atmospheric pressure over the Pacific.
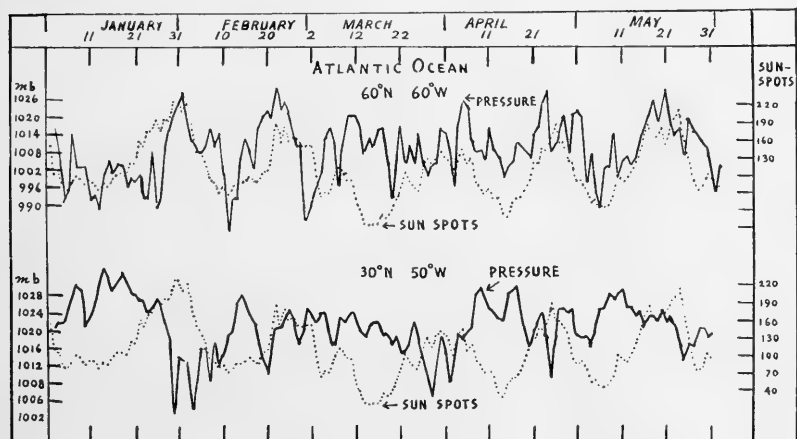
Fig. 7.—Daily sunspot numbers compared with atmospheric pressure over the Atlantic.

In order to determine quantitatively the relation between daily sunspot numbers and atmospheric pressures at different latitudes and longitudes in the northern hemisphere of the earth, the sunspot numbers were correlated with the pressure read from weather maps at the intersections of the 10° lines of latitude and longitude, using the accepted formula:

$$r = \frac{\Sigma ps}{\sqrt{\Sigma p^2 \cdot \Sigma s^2}}$$

in which p represents departures from the mean pressure for 27-day intervals and s represents departures from the mean of the sunspots for the same intervals. There were 173 values of the pressure each day at intersections distributed over the oceans and lands of the Northern Hemisphere between 20° and 70° N. The correlations were computed for twelve 27-day intervals beginning with October 12, 1936, and ending with August 31, 1937. Table 1 shows the correlations for the interval December 5-31, 1936.

The correlations for each interval of 27 days were plotted on maps of the Northern Hemisphere. Each of these maps shows many centers of plus and minus correlation. Figure 8 shows the correlations for the interval December 5-31, 1936, plotted on a map.[11] There are 12 major centers of plus and minus correlations. The plus area near Alaska gives three values exceeding .80, and the negative area at 30° N., 175° E. gives two values of −.83 and −.87. Maps for other periods of 27 days show areas of correlation exceeding .70; but the positions of the centers vary from period to period, showing the complex nature of the forces causing these areas of plus and minus correlation.

In the means of several periods, however, there emerge certain definite relations. The first of these is the latitude relationship. The time covered by the investigation was at the high point of the great solar activity of 1936-1937, and in accord with the results indicated by figure 2, the pressure was higher than normal in high latitudes with each recurrent maximum of sunspots in the 27-day period. This is illustrated by figure 9. From October 12, 1936, to June 12, 1937, the mean of all the correlations at 70° latitude was positive for each period of 27 days and increased as the mean sunspot number increased.

---

[11] The base map is an equal area map of the Good series used by permission of the University of Chicago Press.

TABLE 1.—*Correlations of daily sunspot numbers with the atmospheric pressure (in percent), December 5-31, 1936.*

Long. E. Lat.	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
70° N.	..	..	..	10	..	..	17	..	—19	..	—25	..	08	..	—67	..	—75	..
60°	63	54	17	—09	—29	—36	—39	—44	—47	—55	—57	—52	—55	—70	—72	—65	—85	—70
50°	60	44	23	—36	—77	—76	—75	—51	—43	—40	—40	—48	—72	—79	—84	—77	—78	—70
40°	41	29	21	—24	—59	—84	..	..	..	..	—41	—41	—59	..	—81	—65	—57	—77
30°	29	47	62	25	—22	..	..	—40	38	49	—07	—08	—19	..	—48	—63	—72	—88
20°	..	..	..	50	..	..	..	29	13	—17	16	—36	..	—55	—17	—31	—40	—56
10°	..	..	..	..	..	..	..	..	—11	..	—22	..	..	..	..	..	..	..

Long W. Lat.	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10
70° N.	..	..	24	..	44	..	61	..	11	..	55	..	..	13	..	38	20	10
60°	—41	—13	49	82	87	76	69	07	39	49	62	68	..	..	..	..	..	..
50°	—43	—21	77	81	62	08	—09	30	10	—06	11	28	..	..	..	..	..	..
40°	—56	—35	25	53	40	—33	—70	..	25	—27	—57	—69	..	..	..	..	..	..
30°	—83	—69	—37	20	41	27	07	68	..	—12	—67	—66	..	..	..	..	..	..
20°	—65	—69	..	—52	—38	17	17	44	..	..	..	—11	..	..	..	..	..	..

Fig. 8.—Correlations of daily sunspots and atmospheric pressure, December 5-31, 1936.
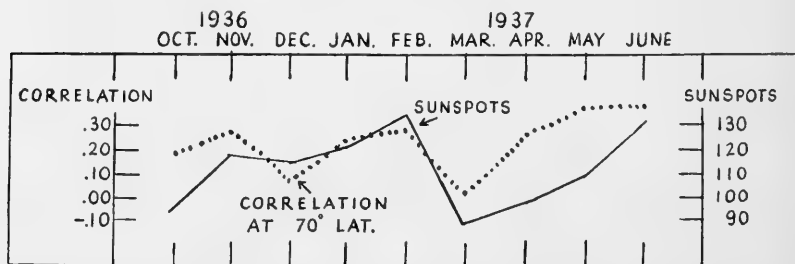
Fig. 9.—Mean correlations at 70° latitude of daily sunspots with atmospheric pressure from October 12, 1936, to June 11, 1937, for each 27-day interval compared with absolute number of sunspots.

At high latitudes in all seasons the average correlation was positive, whereas in latitudes below 50° it was negative. This fact is shown by table 2.

TABLE 2.—*Mean correlations of sunspots and pressure at different seasons*

Lat.	Autumn Oct. 12–Dec. 4	Winter Dec. 5–Feb. 13	Spring Feb. 24–May 15	Summer May 16–Aug. 31	Year
70°	.17	.19	.15	.11	.16
60°	.04	.10	.10	.04	.07
50°	.02	—.03	.01	—.05	—.01
40°	—.01	—.16	—.05	—.05	—.07
30°	—.05	—.13	—.05	.04	—.05
20°	—.10	—.06	.00	.05	—.02

The correlations in table 2 are the mean of about 350 values at each latitude. Although the averages are not high, the results are remarkably consistent in indicating an increased pressure in high latitudes at all seasons with increased sunspots in the short-period oscillations of about 27 days. There is no seasonal difference except in intensity, the correlations being greater in winter when the temperature difference between Pole and Equator is greater. The mean correlations for the year for each latitude are plotted in figure 10.

When the mean correlations for 12 consecutive periods of 27 days at each intersection of 10° lines of latitude and longitude are plotted on a map of the Northern Hemisphere and lines of equal correlation drawn, figure 11 is obtained. It is evident from this figure that there is a mean distribution of positive and negative areas of correlation depending on different conditions at the earth's surface. In the polar region there are positive correlations in all longitudes. In middle latitudes there are negative correlations over the land surfaces of the United States, northern Africa, and southern Asia.

There are also negative correlations over the warm waters of the Gulf Stream from the northern coast of South America to Norway and over the warm waters of the western Pacific from latitude 20° N. to 60° N.; whereas over the colder waters of the Pacific at about longitude 130° to 140°, and over the colder waters of the Atlantic near the coast of Africa, there are positive correlations.

Sir G. C. Simpson disclosed in his studies of the heat balance of the atmosphere that over the land surfaces south of latitude 45° there is an excess of insolation over radiation from the earth in the mean for the year, whereas north of latitude 45° radiation from the earth is in excess of insolation. This condition tends to bring about
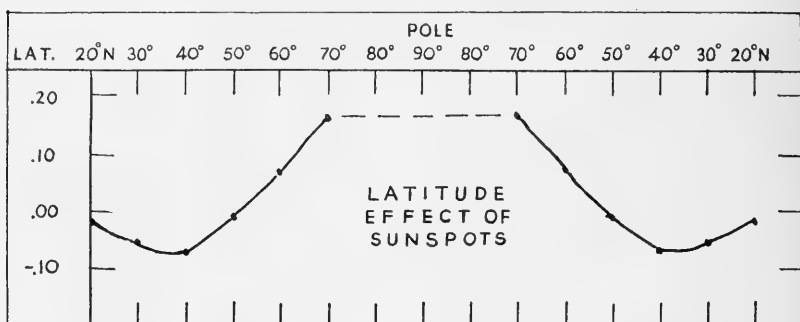
Fig. 10.—Mean correlations of daily sunspots with atmospheric pressure at different latitudes for 12 periods of 27 days, October 12, 1936, to August 31, 1937.
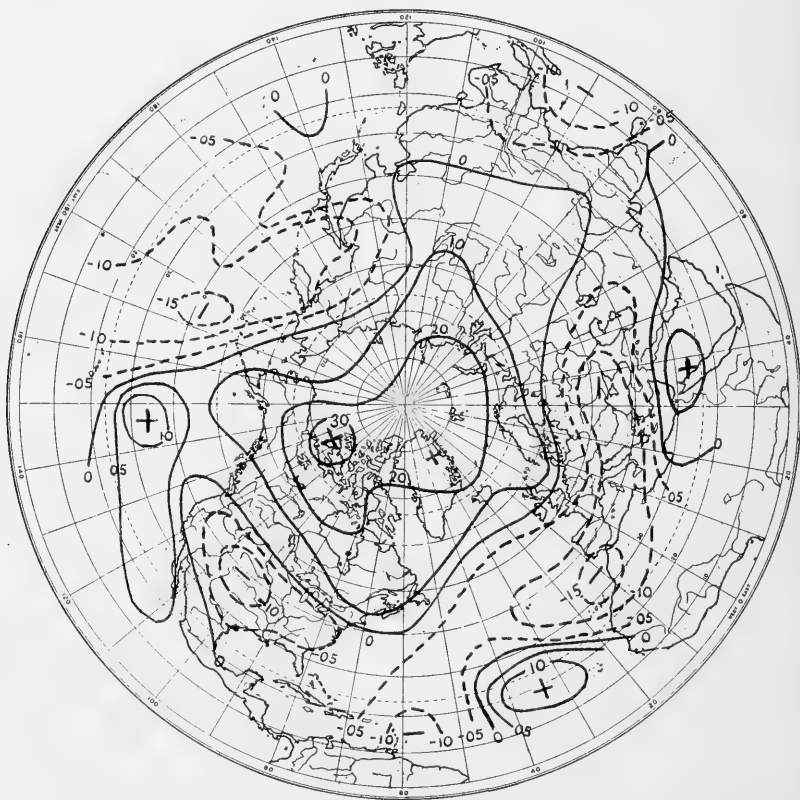
Fig. 11.—Mean correlations of daily sunspots with atmospheric pressure for 12 periods of 27 days, October 12, 1936, to August 31, 1937.

a fall of pressure in latitudes south of 45° and a rise of pressure north of 45° with an increase of solar radiation. Such an increase accompanies increased solar activity. The air flows from the heated areas of southern land surfaces and from the warmer waters of the ocean toward the north, and also toward the colder waters of the oceans in the same latitude, thus offering an explanation of the areas of positive correlation near the west coast of southern California and the west coast of North Africa.

This factor depending on the composition of the earth's surface is subject to a marked seasonal change. The region where outgoing radiation from the earth exceeds incoming radiation from the sun is separated by a line which moves north and south with the seasons. Hence, there are large areas of the earth's surface between 22° N. and 68° N. where the effect of increased solar radiation on pressure is inverted between summer and winter.

This inversion is evident from figure 12. The 12 periods of 27 days between October 12, 1936, and August 31, 1937, were divided into two intervals of six periods, one from October 12 to March 22, called the winter half year, and the other from March 23 to August 31, called the summer half year. A plot of the average correlations for each latitude and longitude is shown in figure 12. The continuous line at each latitude gives a plot of the winter half year, and the dotted line gives a plot of the summer half year. The curve for the winter half year shows two general maxima, one extending from about 0° to 120° E. longitude north of 50° latitude and covering the northern part of the continent, Euro-Asia, and a second extending from 180° to 80° W. covering the western part of the Pacific and North American continent north of 40° latitude. Why this second maximum should be larger than the first is not evident. At 20° N. and 30° N. the position of the positive and negative correlations are more complex, but at each latitude from 20° N. to 70° N. the maxima and minima in the curves for summer tend to be opposite to those for winter.

Even the harmonics of the 27-day solar rotation period show marked relationships to weather changes in the United States and Canada. The half period of 13.5 days, the third harmonic of 9.0 days, the fourth of about 6.8 days, and the sixth and eighth of 4.5 and 3.4 days show a relation to solar changes when the sunspot numbers are analyzed by harmonic analysis.

A plot of analyzed data is shown in figure 13, giving the analyzed values of the daily sunspot numbers and of the daily pressures ob-

served at 8 a.m. each day at certain stations in the United States and
Canada during the early part of 1939. The method of analysis is
described in my paper on "The Sunspot Period" in the Smithsonian
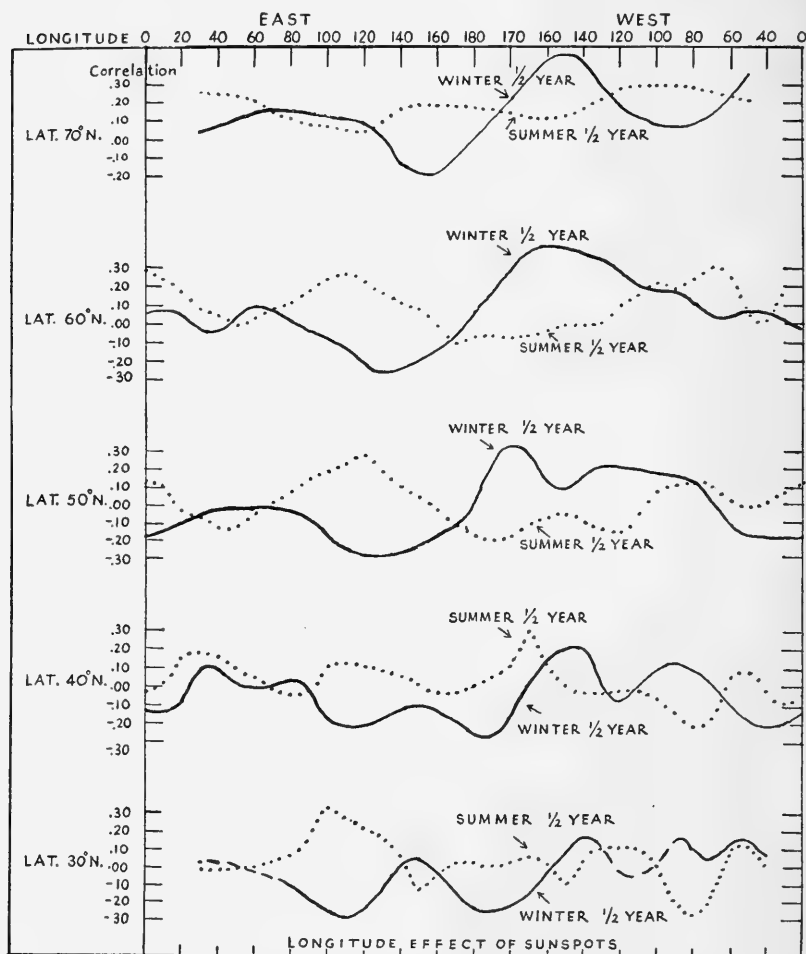
FIG. 12.—Correlation of daily sunspot numbers with atmospheric pressure for
summer and winter half years.

Miscellaneous Collections, vol. 94, No. 10, pp. 1-5. In the plot the
analyzed results for sunspots are shown by dotted curves and for
pressure by continuous curves. The plots were made for stations
showing the highest plus or minus correlations between sunspots and
pressure. Means of three periods were used for the 13.5-day and

9-day periods, and means of nine periods were used for the 4.5-day period. The curves show that at stations like Nottingham, Churchill, and Cochrain in the Hudson Bay region the pressure oscillated mostly in phase opposed to that of sunspots, whereas at stations like
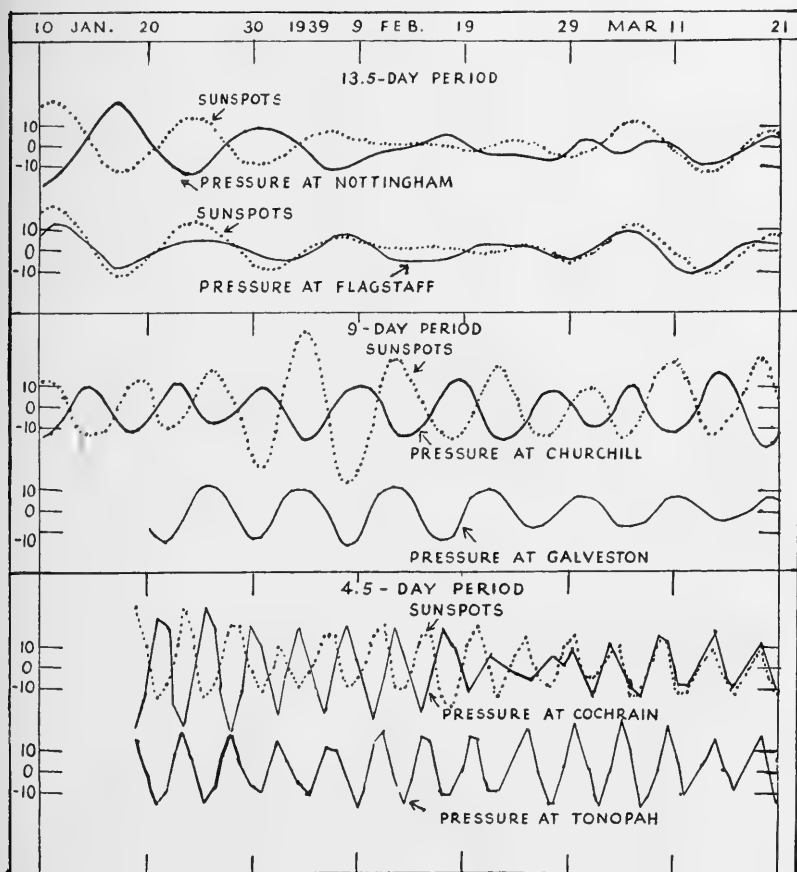
Fig. 13.—Harmonics of the solar rotation period of 27 days in sunspots and in atmospheric pressure.

Flagstaff, Galveston, and Tonopah in the southwestern United States they oscillated in the same manner as the sunspots.

In the 13.5-day period at Nottingham and the 4.5-day period at Cochrain there was a reversal of phase in March 1939. As mentioned before, this change of phase occurs for periods of all length and is due to the fact that when centers of oscillation are formed

they assume the form of a wave and progress with a velocity inversely proportional to the wave length.[12]

Dr. C. G. Rosby has found an explanation for this differential motion in the effect of the earth's rotation on air at different latitudes moving along convex and concave isobaric gradients.[13] However, these movements are undoubtedly modified by atmospheric drift due to differences of temperature and pressure over large areas. This drift tends to carry the system of isobars and winds along with it and is variable in velocity. It is this drift combined with the drift due to the earth's rotation that makes the problem of forecasting difficult, but with sufficient observations and sufficient knowledge it can no doubt be computed.

This investigation of the 27-day period discloses that there are three distinct factors affecting the earth's atmosphere with increased solar activity as shown by sunspot numbers.

1. An increased flow of air from low latitudes to high latitudes acting throughout the year.

2. An increased flow of air from ocean to continent in winter and from continent to ocean in summer, which thus reverses with the season.

3. The formation of systems of circulating winds or waves that drift with velocities proportional to the wave length.

The meteorological changes accompanying sunspot changes of short period are even larger than those accompanying the 11-year sunspot period. It is evident from this fact that it is not sunspot changes that are the direct influence in causing weather, but something associated with them. Various possible relations have been suggested such as electrons coming from the sun, clouds of absorbing matter between the sun and the earth, changes in solar radiation, etc. I have examined several of these suggestions carefully, and my studies convince me that the variations of solar radiation which are being observed by the Smithsonian Institution are the primary causes of weather changes. These observations of solar radiation are made under great difficulties owing to the turbidity of our atmosphere, so that errors of observation have been nearly as large as the real variation of radiation, but when measures of solar radiation at two widely separated stations are compared, the values at each

---

[12] Clayton, H. H., Monthly Weather Rev., vol. 48, No. 3, p. 127, March 1920.

[13] Rosby, C. G., Relation between variation in the intensity of the zonal circulation of the atmosphere and the displacements of the semi-permanent centers of action. Sears Foundation, Journ. Marine Res., vol. 11, No. 1, pp. 38-55, June 21, 1939.

station increase step by step with each other and show distribution curves of the observation in each step which are very similar. Furthermore, each distribution curve indicates a probable error in individual observation of about ±.005 calorie over a range of measurements six times as large as the probable error.[14]

Such a condition might be brought about by an interrelation of the observations; or else, by some absorption in our atmosphere, or in space, occurring simultaneously at the two stations. Both of these suggestions have been advanced. Hence, it is desirable to see whether the measurements of solar radiation are related to visible changes on the sun. If so they must be solar and not terrestrial relationships. The observations of faculae observed at Greenwich were first used as a test. These faculae are visible only on the east and west sides of the sun near the rim and are known to be due to heated matter brought up from the interior of the sun and much hotter than the other parts of the outer surface. Using four years of observation, 1918-1921, means were obtained by the solar radiation measured by the Smithsonian Institution for the day on which the faculae were observed and for the days before and after.[15] The results indicate clearly that the radiation was greatest when faculae were present. This difference was especially striking from September to April, when the solar measurements were best. The measurements of solar radiation were next compared with sunspots crossing the central meridian of the sun, taking $6\frac{1}{2}$ days before and $6\frac{1}{2}$ days after the crossing as representing the side of the sun facing the earth. The average solar radiation on each day indicates that there is a diminution of radiation when the spots are crossing the center of the sun and a marked increase of radiation when the spots are near the eastern and western rim of the sun.[16]

The same effect was even more marked when averages of radiation were computed for clouds of flocculi crossing the sun. The data were obtained from the Ebro Observatory.[17] These comparisons and similar comparisons by Dr. Abbot and Mr. Fowle, are convincing evidence that the Smithsonian Astrophysical Observatory was measuring real solar changes.

[14] Clayton, H. H., The atmosphere and the sun. Smithsonian Misc. Coll., vol. 82, No. 7, p. 2, June 9, 1930. See also vol. 79, No. 4, pp. 50-53.

[15] Clayton, H. H., Solar radiation and weather. Smithsonian Misc. Coll., vol. 77, No. 6, pp. 53-54, June 20, 1925.

[16] Idem, p. 49.

[17] Clayton, H. H., The atmosphere and the sun. Smithsonian Misc. Coll., vol. 82, No. 7, p. 3, June 9, 1930.

Changes in solar radiation affect the atmospheric pressure in the same way as do changes in the number of sunspots. This similarity will be seen by comparing the results described in preceding pages for the 27-day period in sunspots with those found for solar radiation changes in my paper on "The Atmosphere and the Sun," Smithsonian Miscellaneous Collections, vol. 82, No. 7, pp. 5-11, and 30-31, 1930.

Since the effects of increased solar radiation depend in part on the composition of the earth's surface, it is evident that temporary changes at the earth's surface must play a part in the result. When the earth is covered with snow or the waters of the ocean are warmer than usual the effect must be altered. The most recent studies on the influence of changes in water temperatures and of snow covers are those of Sir Gilbert Walker, Dr. C. F. Brooks, and I. I. Schell. However, the present data are too scanty to enable me to get quantitative estimates of the influence of these temporary conditions when solar radiation increases.

√ A study of short-period climatic changes published in the Bulletin of the American Meteorological Society for February 1940 arrived as this paper was on the point of being sent to the printer. In this study Prof. Raymond H. Wheeler describes world-wide temporary changes in climate since 1800. Since 1900 there are sufficient data to connect these changes with the areas of excess and deficiency in pressure accompanying sunspot changes. In 1900 to 1904 when sunspots were at a minimum, the areas of excess pressure (baroplions) were in low latitudes, whereas the pressure was below normal in high latitudes. There resulted a warm-wet period in middle and high latitudes. This condition was repeated in the sunspot minimum of 1913-1915 and again in the sunspot minimum of 1920-1925. On the other hand a cold-dry period occurred in 1917-1920 with high sunspot activity when there were areas of excess pressure in high latitudes having a southward trend of motion. A warm-dry period occurred from 1925-1930 when the areas of excess pressure were being displaced from low latitudes to high latitudes. In this study by Professor Wheeler seasonal changes and changes due to progressive movements of areas of high and low pressures in longitude are not considered, but only general changes occurring simultaneously, mostly over the United States, Asia, Europe, and North Africa.

THE TIME COURSE OF PHOTOSYNTHESIS
AND FLUORESCENCE OBSERVED
SIMULTANEOUSLY

BY

E. D. McALISTER

AND

JACK MYERS

Division of Radiation and Organisms
Smithsonian Institution

THE TIME COURSE OF PHOTOSYNTHESIS AND FLUORESCENCE OBSERVED SIMULTANEOUSLY

BY

E. D. McALISTER

AND

JACK MYERS

Division of Radiation and Organisms
Smithsonian Institution

THE TIME COURSE OF PHOTOSYNTHESIS AND FLUORESCENCE OBSERVED SIMULTANEOUSLY

By E. D. McALISTER and JACK MYERS [1]

Division of Radiation and Organisms, Smithsonian Institution

The bulk of our knowledge of chlorophyll photosynthesis has come from observations on carbon dioxide assimilation and oxygen production during the process in a living plant. Recently, fluorescence studies have also contributed to the development of theories for the kinetics of photosynthesis (cf. Franck and Herzfeld, 1937, Kautsky and Hormuth, 1937, Ornstein et al., 1938). Unfortunately, there is little agreement between the experimental data of these various groups of workers, which have been obtained under different conditions and on various plant materials. Their contributions have been of great value in suggesting that changes in intensity of fluorescence are related to changes in the rate of photosynthesis during the induction period, and consequently that there must be a relationship between the two phenomena.[2] However, the lack of other than inferential information on the exact state of photosynthesis corresponding to a particular state of fluorescence leaves the relationship on insecure ground. These workers have not been unaware of this but have lacked facilities for following changes in carbon dioxide assimilation or oxygen production with a rapidity at all comparable to that of their fluorescence observations.

---

[1] National Research Fellow.

[2] The concept of a relationship between intensity of fluorescence and rate of photosynthesis does not require that fluorescence enter into the process of photosynthesis in any way. The chlorophyll in the plant, after absorbing radiation, can dispose of this energy in various ways. It is either used in photosynthesis or some other photochemical process, is lost as heat, or is emitted as fluorescence radiation of longer wave length (red). The distribution of energy among these three outlets must change during the induction period, as shown by all the fluorescence and photosynthesis induction curves reported in the literature. In other words, it is believed possible that changes in fluorescence can tell us something about the photochemical processes; but it is not held that fluorescence enters in any way into the process of photosynthesis. The amount of energy appearing as fluorescence is very small compared to that used in photosynthesis. According to the measurements of Vermeulen et al. (1937), only 0.1 to 0.2 percent of the energy absorbed by *Chlorella* is re-emitted as fluorescence.

The rapid spectrographic method of carbon dioxide measurement developed in this laboratory fulfills this need. It is the purpose of this preliminary report to present simultaneous records of induction in fluorescence and photosynthesis obtained on two different types of plants and over a wide range of experimental conditions. To the writers' knowledge this is the first time that these two phenomena have been observed simultaneously during the induction period. Such an attack gives promise of clarifying the interpretation of both phenomena. As will be seen below, it has been possible to distinguish two different processes involved in the induction period. In one of these intensity of fluorescence and rate of carbon dioxide uptake are related inversely; in the other a direct relationship exists.

The only observations on fluorescence and photosynthesis during the steady state appearing in the literature are those of Wassink et al. (1938, 1939), using *Chlorella*. The present work also includes further measurements during the steady state in wheat.

The authors take pleasure in acknowledging their indebtedness to Dr. C. G. Abbot and to Dr. E. S. Johnston for their interest in, and support of, this work.

EXPERIMENTAL PROCEDURE

Two types of plant material have been used. Wheat (variety, *Marquis*) [3] was grown for 4 to 8 days on cloth netting over running tap water and with 300 to 400 foot-candle illumination from an unfiltered tungsten lamp. Measurements were made on eight or nine young plants in a cylindrical, water-jacketed chamber of about 100 cc. volume similar to that previously described by McAlister (1937).

Chlorella pyrenoidosa [4] was grown in 250-cc. Erlenmeyers held in a mechanical shaker in a water bath thermostated at 23° C., and with either air or air containing 4 percent carbon dioxide bubbled through. Light intensity of 300 to 400 foot-candles was provided by a tungsten lamp placed beneath the glass bottom of the bath and filtered through 2 cm. of water. This intensity corresponds to about 3×10^4 ergs/cm.^{2}/sec. of visible radiation. Knop's nutrient solution was used with the addition of 0.1 cc. per liter of "solution A" of Hoagland and Arnon (1938), as recommended by Emerson and Lewis (1939). The addition of the microelements of "solution A" (boron,

---

[3] Seed kindly supplied by H. H. McKinney, of the U. S. Department of Agriculture.

[4] From a culture originally obtained through the courtesy of Dr. Robert Emerson.

manganese, zinc, copper, molybdenum) gave a noticeably more rapid growth than occurred in their absence. Cultures containing about 0.3 cc. of cells per 100 cc. were harvested by centrifuging, and the cells resuspended in fresh nutrient of the same composition for the experimental work. Forty cc. of an algal suspension containing 0.2 to 0.4 cc. of packed cells was placed in a glass chamber measuring 0.6 × 10 × 20 cm. This density of cells absorbed about 50 percent of the incident beam. An air stream of up to 50 cc./sec. was forced through the suspension, entering at the bottom through fine holes in a glass tube. This arrangement broke up the air stream into fine bubbles, providing a maximum area of contact between liquid and gas. Constant temperature of 24° C. was maintained by immersion in a small water bath.

Instead of the closed system and recirculation method previously used (McAlister, 1937, 1939), a constant flow of gas was passed through the plant chambers without recirculation. A spectrographic analysis of the effluent gas from the plant chamber then gives a direct measure of the rate of carbon dioxide uptake or production by the plants. The constant-flow method has an additional advantage in that the plants are kept under a constant environment. Before reaching the plant chamber the gas flow was divided into two portions, "A" and "B." Part "A" continued into the plant chamber at a constant rate of flow of up to 100 cc./sec. as measured by a Venturi gauge. By means of a two-way stopcock part "B" could be either discarded or passed into the optical absorption cell of the spectrograph, as desired. By means of another stopcock the effluent gas from the plant chamber could be either passed into the absorption cell or discarded. This arrangement permitted an easy comparison of the effluent and influent air of the plant chamber. A water-cooled condenser, through which the air passed before entering the absorption cell, removed enough water vapor from the air to prevent condensation on the windows of the cell. Condensation on the optical parts of this cell was further avoided by maintaining it 3° or 4° C. above the temperature of the air stream.

The spectrographic apparatus previously used has been modified in several respects in order to adapt it to the present work. The optical path of the absorption cell has been shortened to about 20 cm. to permit analysis of higher concentrations of carbon dioxide. Its volume is about 70 cc. Because of the small changes in carbon dioxide to be measured, it has been necessary to amplify the indications of the galvanometer used for reading the thermocouple current. A well-defined and uniformly intense rectangle of light is reflected by

the mirror of the primary galvanometer so that it moves across an opaque straight-edge partly covering a Weston photronic cell. Current from the photronic cell actuates a secondary galvanometer. The amplification thus obtained can be varied from 1 to 500 times by changing the intensity of the rectangle of light falling on the photocell. An amplification of $50\times$ was usually sufficient. The amplification factor was measured and found to be constant well within the other experimental errors involved, particularly that involved in the zero drift.

Continuous recording has been substituted for the alternate 30-second readings previously taken. A light spot from the secondary galvanometer makes a continuous record on a sheet of photographic paper held on a drum which is rotated at constant speed by a synchronous motor. This procedure does not permit alternate "zero" readings to be taken and hence makes it impossible to eliminate the slow "zero drifts" which are apparent on many of our records.

Illumination was provided by two 1,000-watt projection bulbs. A uniformly intense spot of light was focused on the plant chamber with spherical reflectors (15-inch diameter, 9-inch focal length). This light was filtered through 13 cm. of water and 6 cm. of a solution of copper nitrate of such concentration that the plants received no light of wave length longer than 6400 A. Incident intensities were varied by use of a series of screens and were measured by means of a vacuum thermocouple and microammeter. No voltage regulator was available; the variation in incident intensity caused by fluctuations in line voltage never exceeded 5 percent during the short periods of illumination used. The "high intensity" commonly used was about 60×10^4 ergs/cm.^{2}/sec. "Low intensity" was a fifth of this unless stated otherwise.

Fluorescence intensity was measured by a circular, barrier-type photocell ("Electrocell") of 44 mm. effective diameter connected to a Moll galvanometer of 1.2-second period. The photocell disk was covered by two filters, a Corning H. R. red (3.6 mm.) and a blue-purple Corex A (4.2 mm.). These filters allowed only light of wave length longer than 6500 A to reach the photocell. The red filter itself was found to fluoresce strongly when illuminated. This feature was reduced to an unobjectionable minimum by placing the purple filter in front of the red so as to absorb most of the radiation causing the fluorescence.

In studies on wheat the photocell was placed at one side of the plant chamber facing the plants and just out of the incident beam;

in the *Chlorella* experiments it was placed immediately behind the rectangular chamber.

With the photocell placed so that it received directly the full intensity of the light incident on the plants, the galvanometer deflection was less than 2 percent of that produced by the steady-state fluorescence of plant material. This galvanometer also records on the same photographic paper on the rotating drum. Perfect time alignment of the "fluorescence" and "carbon dioxide" galvanometer indications is provided by a narrow slit parallel to the axis of the drum, through which both spots must pass.

RESULTS

A number of induction curves, selected from the several hundred which have been obtained, are presented on the following pages. The curves have been so selected as to include representative data illustrating the induction behavior under a wide range of experimental conditions. Figures 1 to 11 are photographic reproductions of the original galvanometer tracings. In each pair the upper curve is the recording of the fluorescence intensity; the lower, the recording of the rate of carbon dioxide uptake. In some cases the tracings have been darkened with India ink to insure their reproduction. Small horizontal arrows have frequently been added to mark the first appearance of the fluorescence tracing on the original record.

The procedure used in obtaining these induction curves was as follows: The recording drum was started about a minute before the beginning of illumination and continued for a minute or so after the plant was darkened. The period of illumination was usually 4 minutes. Vertical lines have been drawn on the records to indicate the times of transition from dark to light and from light to dark. Dotted lines have been added to show the probable course of the "dark" reading (respiration rate and "zero" of fluorescence), interpolated through the light period. One-minute intervals are indicated by vertical dashes above the fluorescence zero line.

In a number of cases, and particularly with suspensions of algae, it has been desirable to observe the time over which an instantaneous plant response is spread by our instruments. This has been accomplished by entirely stopping the gas flow for a short time (15 seconds) during a dark period, allowing the respired carbon dioxide to accumulate. The resumption of gas flow washes the accumulated carbon dioxide through the system and produces a wedge-shaped dip in the carbon dioxide curve (see curves 2, 5, and 8 of fig. 8). The

width of this wedge approximates the time response of the instruments to an instantaneous change in rate of the same magnitude. For wheat at a flow rate of 100 cc./sec. this time is about 6 seconds, and for *Chlorella* at 50 cc./sec. it is 15 seconds. The proportionately longer time in the algal suspension is apparently due to the liquid-gas diffusion lag. Thus in the recording of the rate of carbon dioxide uptake there appears both a "smearing out" of the plant response (as discussed above) and a lateral shift due to the time of transit of gas from the plant chamber to the absorption cell. The lag in fluorescence recording is merely the 1.2-second period of the galvanometer.

In order to obtain a comparison of respiration and photosynthesis, the influent gas stream has been occasionally by-passed directly into the absorption cell, usually for 30- or 45-second periods (as described above, p. 3). This is seen in the curves as a short horizontal shelf which gives a somewhat discontinuous appearance to the curves but establishes the level of respiration.

Figure 1 illustrates the behavior of wheat in normal air. At high intensities (40 to 60×10^4 ergs/cm.^{2}/sec.) and after a long dark rest the fluorescence intensity rises rapidly to a maximum and then falls off more slowly toward a final steady value. During this time the rate of carbon dioxide uptake has risen to a steady value. Comparison of curves 1 and 2 indicates that both photosynthesis and fluorescence are influenced by the length of the preceding dark rests. Furthermore, when the dark rest is not sufficiently long, the preceding light treatment is also of importance, as shown by curves 3 and 4. Under low light (4 to 10×10^4 ergs/cm.^{2}/sec.) (curve 5) or short dark rests (curves 6 and 7) both photosynthesis and fluorescence approach a rectilinear course in their attainment of the final steady state.

Figure 2 demonstrates the effects of low oxygen and low carbon dioxide pressures. Behavior of wheat in "tank" nitrogen [5] is shown in curve 1. The fluorescence curve has the same general features as the fluorescence curve in air, except that the maximum is reached more slowly and the decay is more gradual. The rate of respiration in tank nitrogen is about one-half that in air (see curves 1 and 2 of figures

---

[5] A good grade of "water-pumped" compressed nitrogen. While no oxygen analyses on this are available, it is reasonably certain that the oxygen content was less than $\frac{1}{2}$ percent. Complete removal of oxygen was impossible at the high rate of flow used. This is referred to throughout the paper as tank nitrogen, low oxygen, or $\frac{1}{2}$ percent oxygen.
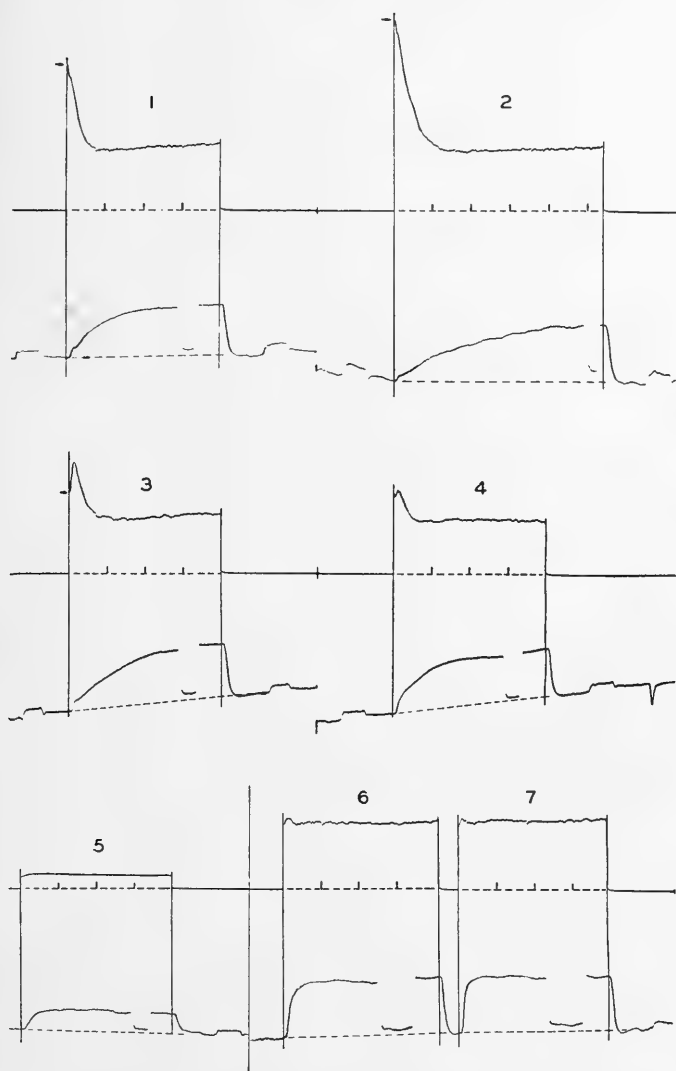
FIG. 1.—The induction behavior of wheat in normal air. The effects of the preceding light and dark treatment.

1. In high light after 10 minutes light, 20 minutes dark rest.
2. In high light after 10 minutes light, 60 minutes dark rest.
3. In high light after 40 minutes light, 12 minutes dark rest.
4. In high light after 4 minutes light, 12 minutes dark rest.
5. In low light after 10 minutes dark rest.
6. In high light after 2 minutes dark rest.
7. In high light after ½ minute dark rest.
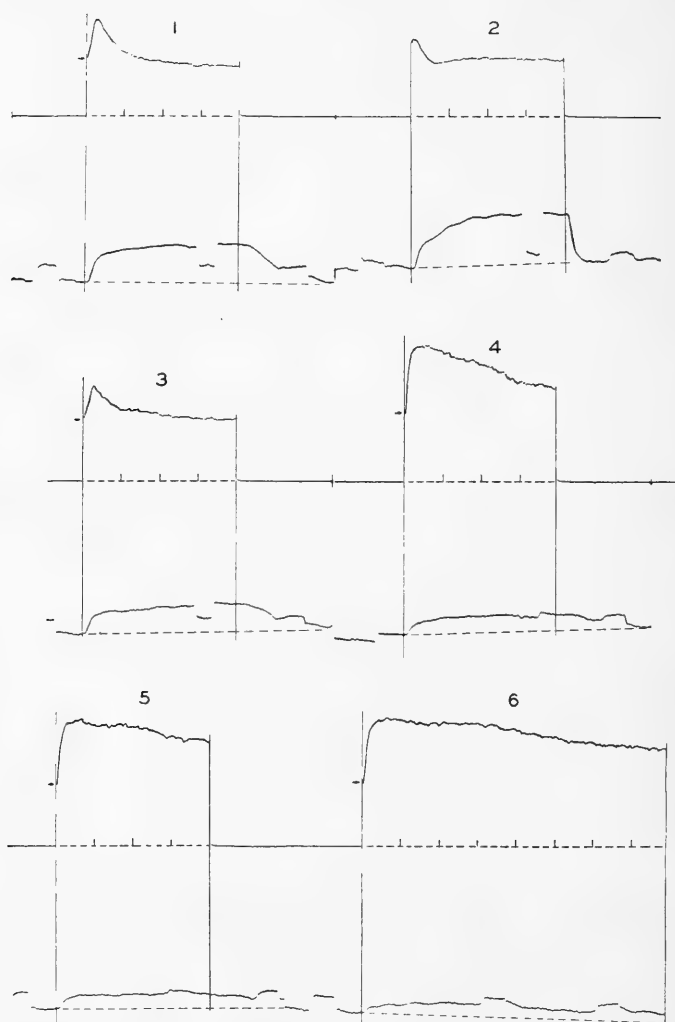
FIG. 2.—The induction behavior of wheat in low oxygen pressure. The effects of varying carbon dioxide concentrations. All curves taken in high light, after 10 minutes in high light and normal air, 10 minutes dark rest with specified carbon dioxide concentration in commercial nitrogen.

1. 0.006 percent carbon dioxide in nitrogen.
2. In normal air.
3. 0.004 percent carbon dioxide in nitrogen.
4. 0.0015 percent carbon dioxide in nitrogen.
5. 0.0006 percent carbon dioxide in nitrogen.
6. Zero carbon dioxide in nitrogen.

3 or 6). The apparently higher respiration rate in the nitrogen than in air (curve 2) is due to the increased sensitivity of our instruments at the lower carbon dioxide concentration of the tank nitrogen (about 0.006 percent). In examination of all the curves it must be remembered that the sensitivity of the spectrographic method is higher at lower concentrations of carbon dioxide. If the carbon dioxide concentration is still further reduced by shunting a measured portion of the gas through soda-lime, the series of curves 3, 4, 5, and 6 is obtained for different carbon dioxide levels. It is apparent that carbon dioxide has a (direct or indirect) quenching effect on the fluorescence. The "dark pick-up" exhibited by these and other curves for low carbon dioxide concentrations will be discussed below.

The effect of decreased oxygen pressure is seen in comparing curves 1 and 2 of figure 3. In 20 percent oxygen the induction in carbon dioxide uptake is longer, although the fall in fluorescence is much more rapid than in low oxygen. In normal air, apparently owing to changes within the plant (curves 3 and 5), the fluorescence decay is even more rapid and actually produces a minimum in the fluorescence curve. When all carbon dioxide is removed from air or from tank oxygen, curves such as 4 and 6 are obtained. The rate of carbon dioxide production is at first decreased but later builds up again to approximately the rate of dark respiration. In no case is there a fluorescence minimum in the absence of carbon dioxide.

Figure 4 shows the peculiar effects of high carbon dioxide on the induction in fluorescence and carbon dioxide uptake in wheat. As seen in curves 1 and 2 the fluorescence falls rapidly to a minimum, followed by a rise to a second maximum and then a decrease to the level of the steady value. Simultaneously the rate of carbon dioxide uptake goes through a series of convolutions which seem to be correlated with the fluorescence changes. This behavior occurs also under low oxygen pressures as shown by curves 3 and 4. The carbon dioxide records here are very irregular, owing to incomplete premixing of the carbon dioxide added to the tank nitrogen.

The curves of figure 5 and curves 5 and 6 of figure 4 show the transition in behavior from air to higher carbon dioxide concentrations.

Figure 6 illustrates the induction behavior accompanying changes in light intensity or in carbon dioxide concentration. A sequence of light intensities (without intervening dark periods) is shown in curve 1 for 0.03 percent carbon dioxide in air, and in curve 2 for 0.03 percent carbon dioxide in nitrogen. The induction effects seem to be somewhat more pronounced in air than under low oxygen pressure.
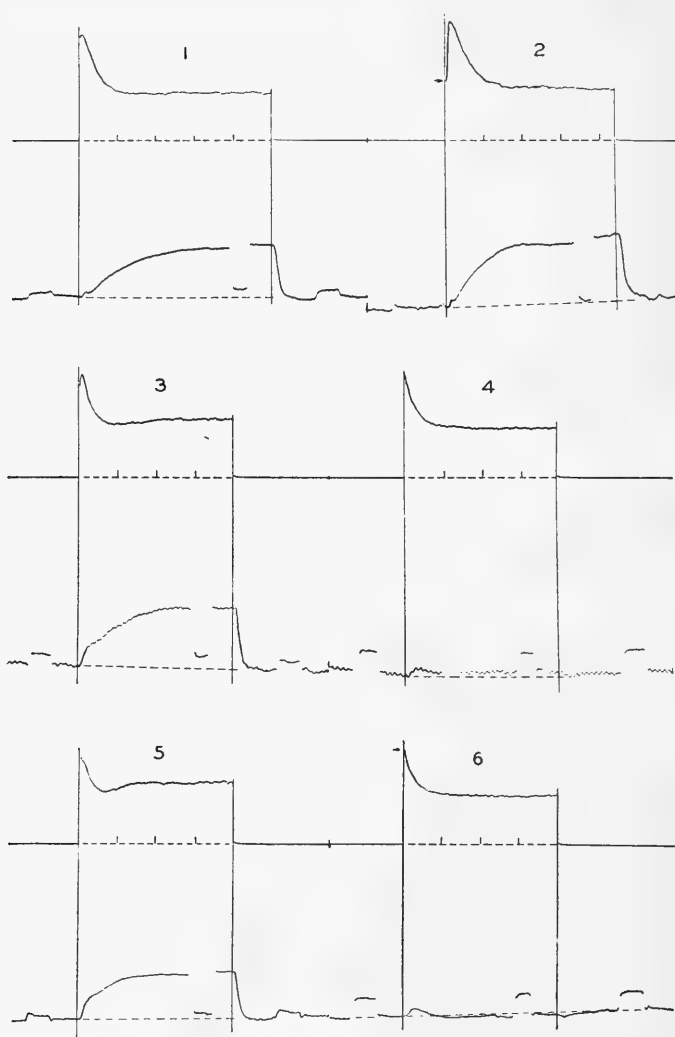
Fig. 3.—The induction behavior of wheat at high light intensities. The effects of oxygen and carbon dioxide pressures.

1. In 0.03 percent carbon dioxide, 20 percent oxygen; after 15 minutes light, 30 minutes dark rest.
2. In 0.03 percent carbon dioxide, low oxygen; after 15 minutes light, 30 minutes dark rest.
3. In 0.03 percent carbon dioxide, 20 percent oxygen; after 4 minutes light, 10 minutes dark rest.
4. In zero carbon dioxide, 20 percent oxygen; after 4 minutes light, 10 minutes dark rest.
5. In 0.03 percent carbon dioxide, 20 percent oxygen; after 15 minutes light, 10 minutes dark rest.
6. In zero carbon dioxide, "tank" oxygen, after 15 minutes light, 10 minutes dark rest.
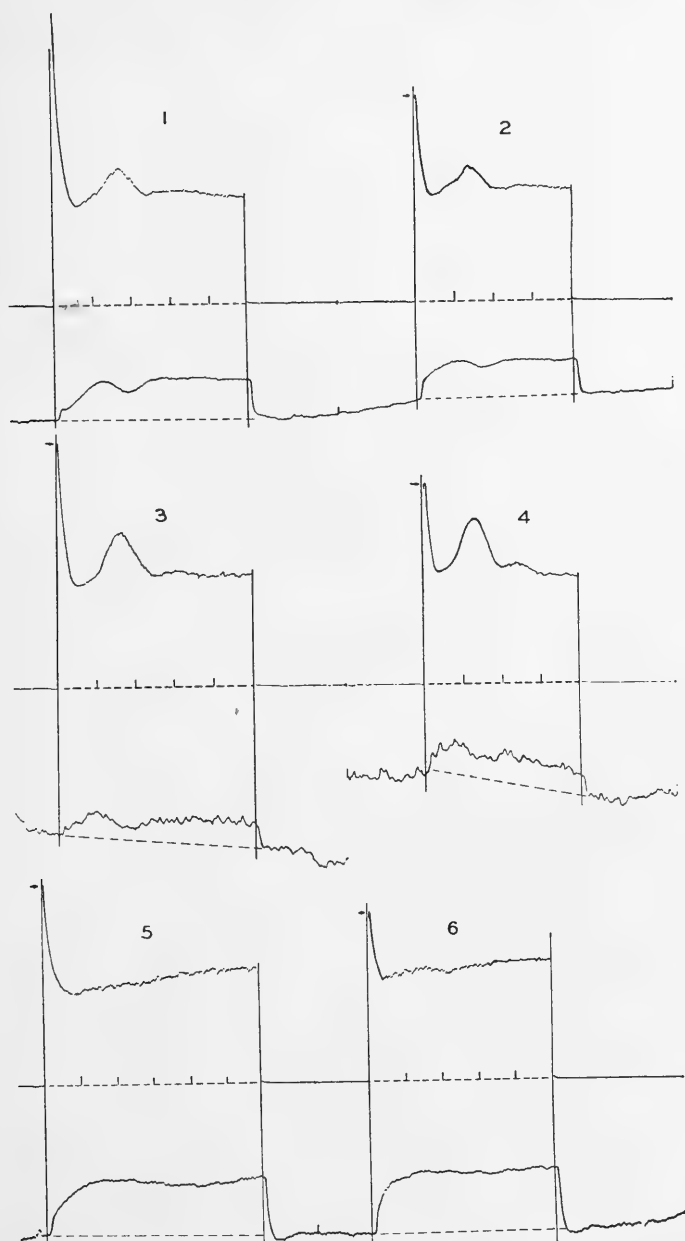
Fig. 4.—The induction behavior of wheat in high light intensities
and high carbon dioxide pressures.

1. In 0.36 percent carbon dioxide in air, after 10 minutes light, 10 minutes
   dark rest.
2. In 0.36 percent carbon dioxide in air, after 5 minutes light, 5 minutes
   dark rest.
3. In 0.36 percent carbon dioxide in nitrogen, after 10 minutes light, 20 min-
   utes dark rest.
4. In 0.36 percent carbon dioxide in nitrogen, after 5 minutes light, 5 min-
   utes dark rest.
5. In normal air, after 10 minutes light, 10 minutes dark rest.
6. In normal air, after 6 minutes light, 5 minutes dark rest.
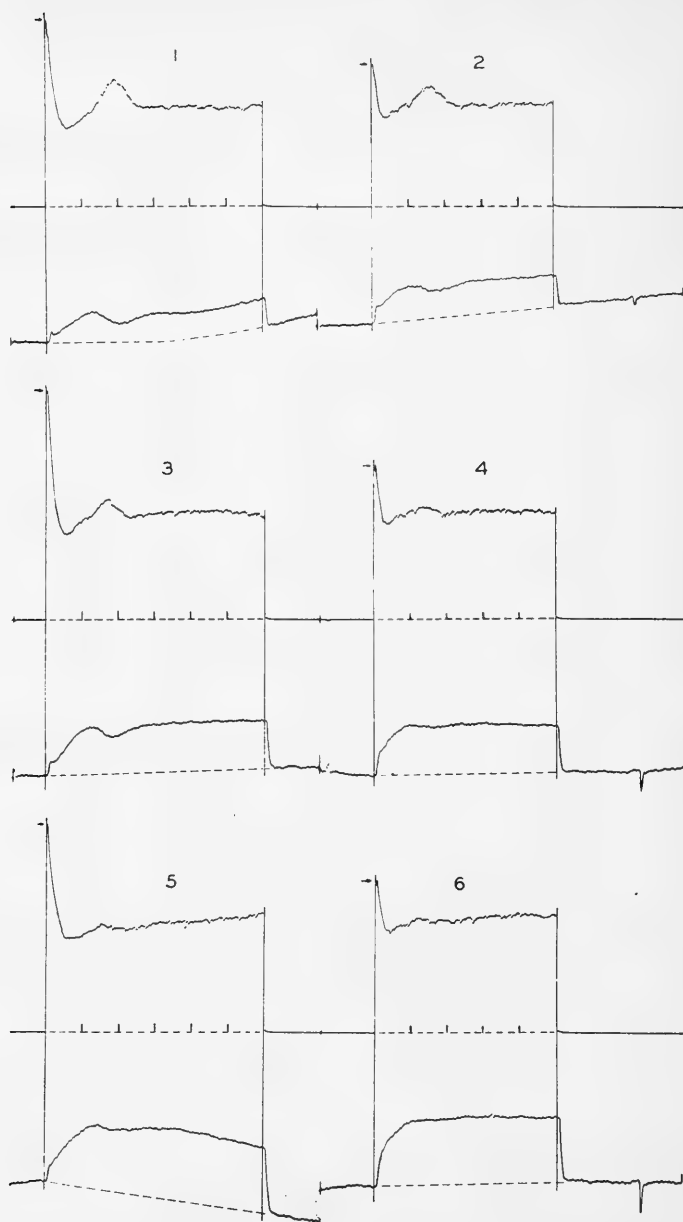
FIG. 5.—The induction behavior of wheat in high light intensities and high carbon dioxide pressures (in air). The effect of carbon dioxide pressure.

1. In 0.24 percent carbon dioxide, after 10 minutes light, 10 minutes dark rest.
2. In 0.24 percent carbon dioxide, after 6 minutes light, 5 minutes dark rest.
3. In 0.12 percent carbon dioxide, after 10 minutes light, 10 minutes dark rest.
4. In 0.12 percent carbon dioxide, after 6 minutes light, 5 minutes dark rest.
5. In 0.07 percent carbon dioxide, after 10 minutes light, 10 minutes dark rest.
6. In 0.07 percent carbon dioxide, after 6 minutes light, 5 minutes dark rest.
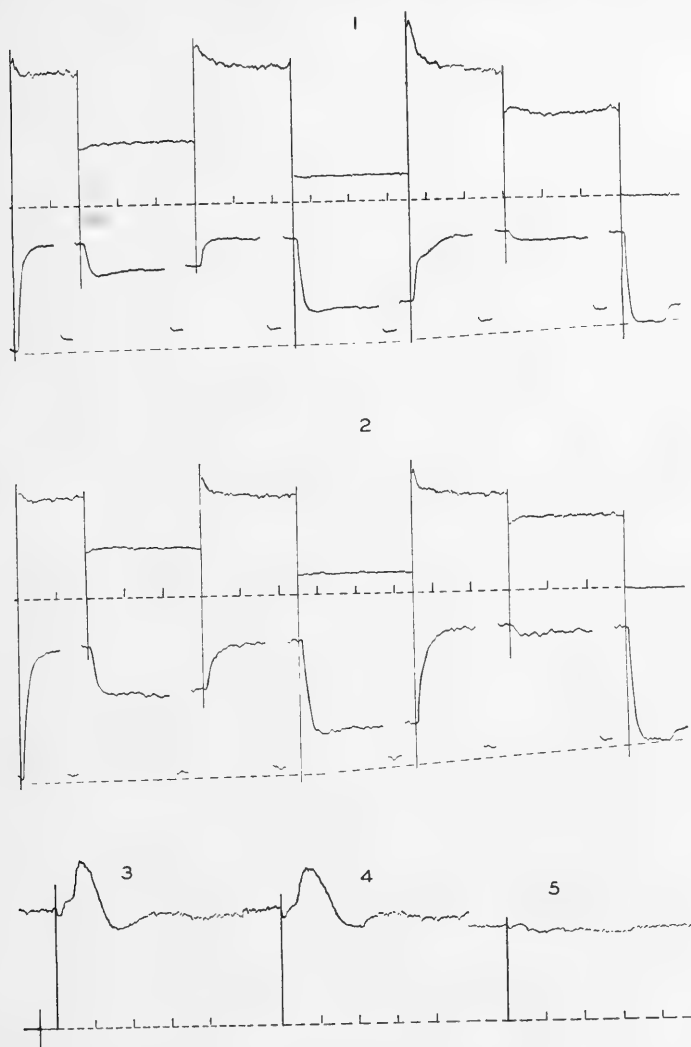
FIG. 6.—The induction behavior of wheat in response to changes in light and carbon dioxide pressure.

1. A sequence of intensities: (in relative units) 100, 49, 100, 21, 100, 74, zero. In normal air.
2. A sequence of intensities: (in relative units) 100, 49, 100, 21, 100, 74, zero. In 0.03 percent carbon dioxide in nitrogen.
3. Fluorescence only, in high light throughout. Carbon dioxide changed from 0.03 to 0.4 percent.
4. Fluorescence only, in high light throughout. Carbon dioxide changed from 0.03 to 4.0 percent.
5. Fluorescence only, in high light throughout. Carbon dioxide changed from 0.4 to 4.0 percent.
(For 3, 4, 5 vertical lines represent time of change in carbon dioxide concentration.)

Curves 3, 4, and 5 show the course of intensity of fluorescence following sudden changes in carbon dioxide concentration.

Unfortunately, our apparatus does not permit us to follow changes in the rate of carbon dioxide uptake accompanying such changes in carbon dioxide pressure, or to measure the final rate of photosynthesis in 4 percent carbon dioxide. However, we have been able to establish from steady-state measurements that at the high light intensity used (about 60×10^4 ergs/cm.^{2}/sec.) this wheat was under a carbon dioxide limitation at 0.03 percent carbon dioxide and not far from a light limitation at 0.4 percent carbon dioxide. The increase in the steady rate of photosynthesis from 0.03 to 0.4 percent carbon dioxide is about threefold; in comparison the change from 0.4 to 4 percent must have been small. It is highly probable here that the "burst" of fluorescence is associated with an increase in rate of photosynthesis. It is to be noted that the reverse case (not illustrated) of changing from 0.4 to 0.03 percent, and from 4 to 0.03 percent gave rise to changes in fluorescence so small as to be negligible compared to those of curves 3 and 4 of figure 6.

A number of experiments have been made on the steady-state behavior of photosynthesis and fluorescence in wheat. The technique used is illustrated in figure 7. The plants were exposed to a given light intensity for 10 minutes. The recording drum was then started and a record taken for the succeeding 3-minute period. A reading on the influent air was made during each interval. This procedure was repeated for each light intensity studied. Thermocouple readings of the incident light intensity were taken every 15 seconds during the recording in order to average out the effects of varying line voltage.

The induction behavior of *Chlorella* is illustrated in figures 8, 9, and 10. The behavior of cells cultured in 4 percent carbon dioxide resembles that of wheat, as shown by curves 1 and 2 of figure 8. Cells grown in air behave very differently. As shown in curves 3 to 8, the rate of carbon dioxide uptake follows a course similar to that found by Aufdemgarten (1939a) for *Stichococcus*. In comparison to the final value the early fluorescence maximum is not nearly as high as in wheat and is followed by a rapid decline to a pronounced minimum. A correlation between the minima in fluorescence intensity and in rate of carbon dioxide uptake is evident from these curves. A similar course is followed at higher carbon dioxide concentrations, as shown in curves 1, 2, and 3 of figure 9. The effect of light intensity is demonstrated in curves 4 to 10 of figure 9.

Figure 10 shows the behavior of *Chlorella* under various low carbon dioxide concentrations. As the carbon dioxide concentration is decreased the minima in both fluorescence and carbon dioxide uptake tend to disappear. (The peculiar appearance of the carbon
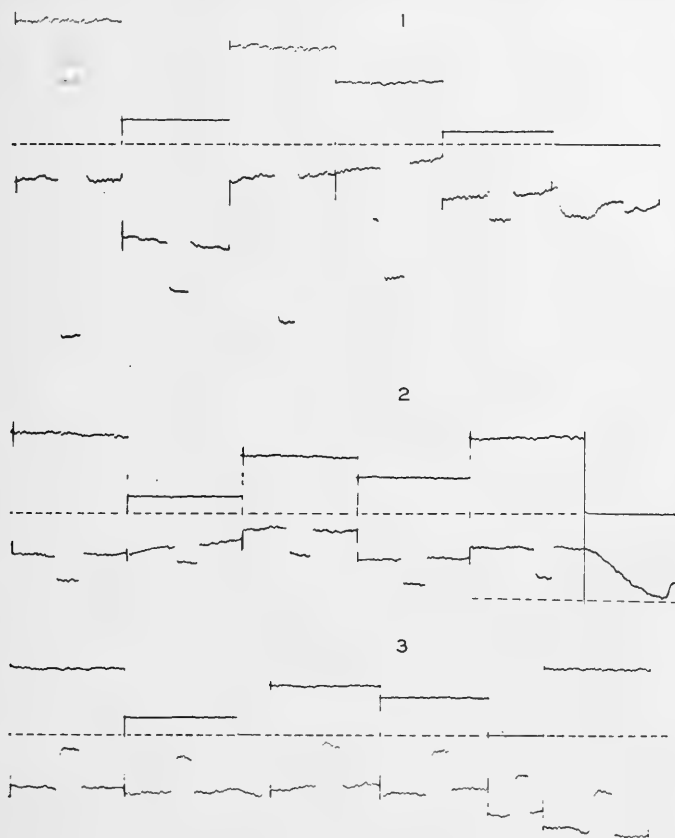
Fig. 7.—The steady-state behavior of wheat in response to light intensity. Record taken only from the 10th to 13th minute of illumination at each intensity. Highest intensity about 60×10^4 ergs/cm.^{2}/sec. in each series.

1. In 0.03 percent carbon dioxide in nitrogen. Average relative light intensities in sequence: 99.8, 21.6, 79.2, 50.0, 11.6, zero.
2. In about 0.006 percent carbon dioxide in nitrogen. Average relative light intensities in sequence: 65, 14.4, 48.6, 30.7, 64.4, zero.
3. In zero carbon dioxide in air. Average relative light intensities in sequence: 60.9, 13.8, 46.7, 32.3, zero, 62.3.

dioxide record of curve 1 is due to the fact that the zero drift of the primary galvanometer shifted the light spot entirely away from the exposed area of the amplifier photocell.) It is apparent in figure 10 that for *Chlorella* the rate of respiration measured 90 seconds after
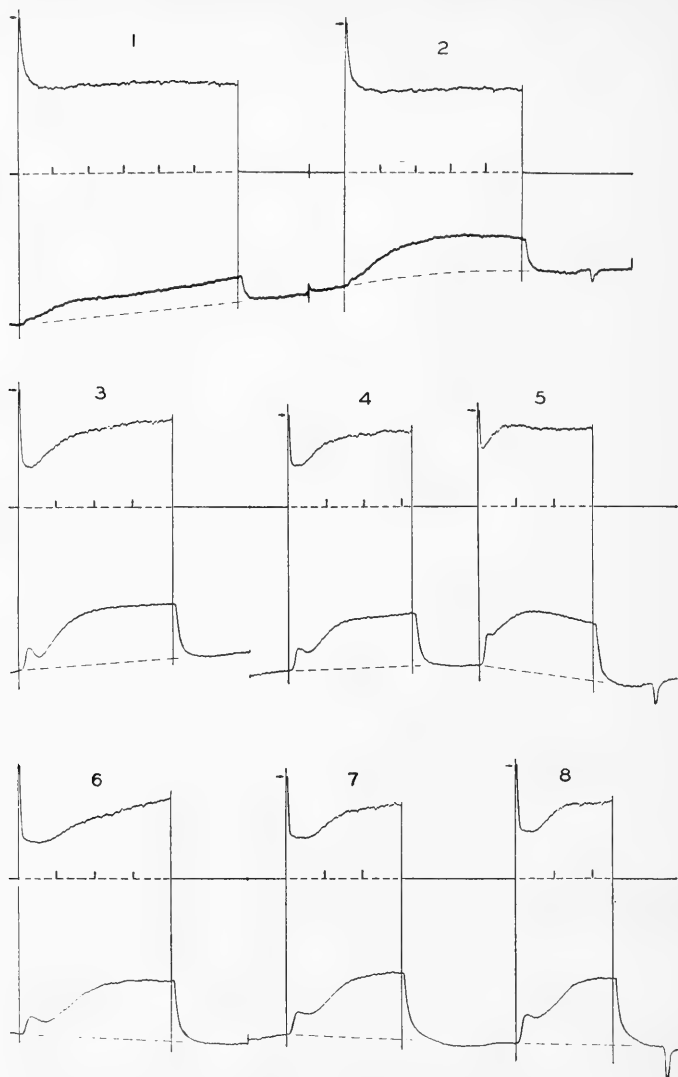
Fig. 8.—The induction behavior in high light of *Chlorella* cultured under two different conditions. The effect of the preceding dark rest.

1 and 2. *Chlorella* grown in 4.0 percent carbon dioxide, studied in 0.24 percent carbon dioxide.
          1. after 10 minutes light, 20 minutes dark rest;
          2. after 6 minutes light, 10 minutes dark rest.
3, 4, and 5. *Chlorella* grown in and studied in 0.03 percent carbon dioxide.
          3. after 3 minutes light, 40 minutes dark rest;
          4. after 4 minutes light, 10 minutes dark rest;
          5. after 3 minutes light, 2 minutes dark rest.
6, 7, and 8. The same suspension of *Chlorella* as 3, 4, and 5 (above), left overnight in 0.33 percent carbon dioxide and low light (10×10^4 ergs/cm.²/sec.). Studied in 0.03 percent carbon dioxide, high light.
          6. after 30 minutes light, 60 minutes dark rest;
          7. after 4 minutes light, 10 minutes dark rest;
          8. after 3 minutes light, 3 minutes dark rest.
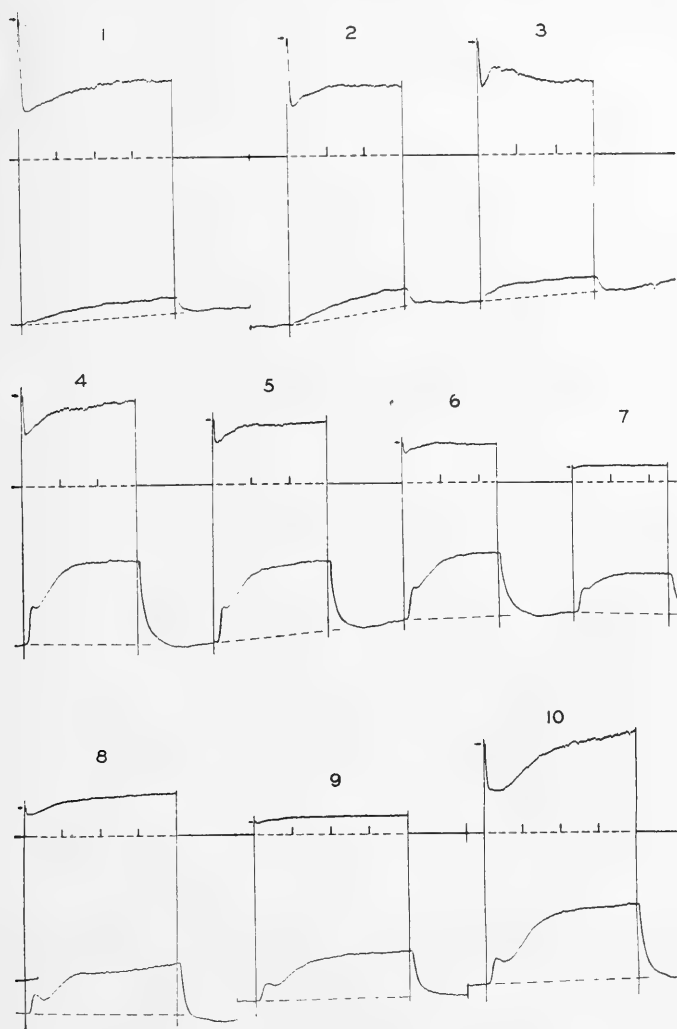
FIG. 9.—The induction behavior of *Chlorella* grown in air.

1, 2, and 3. In 0.33 percent carbon dioxide and high light after dark rests of
    25, 10, and 2 minutes respectively.
4, 5, 6, and 7. In 0.03 percent carbon dioxide and after 2-minute dark rests.
    Sequence of light intensities: (in relative units) 100, 74, 49, 21
    respectively.
8, 9 and 10. In 0.03 percent carbon dioxide and after 10-minute dark rests.
    Sequence of light intensities of: (in relative units) 49, 21, 100
    respectively.
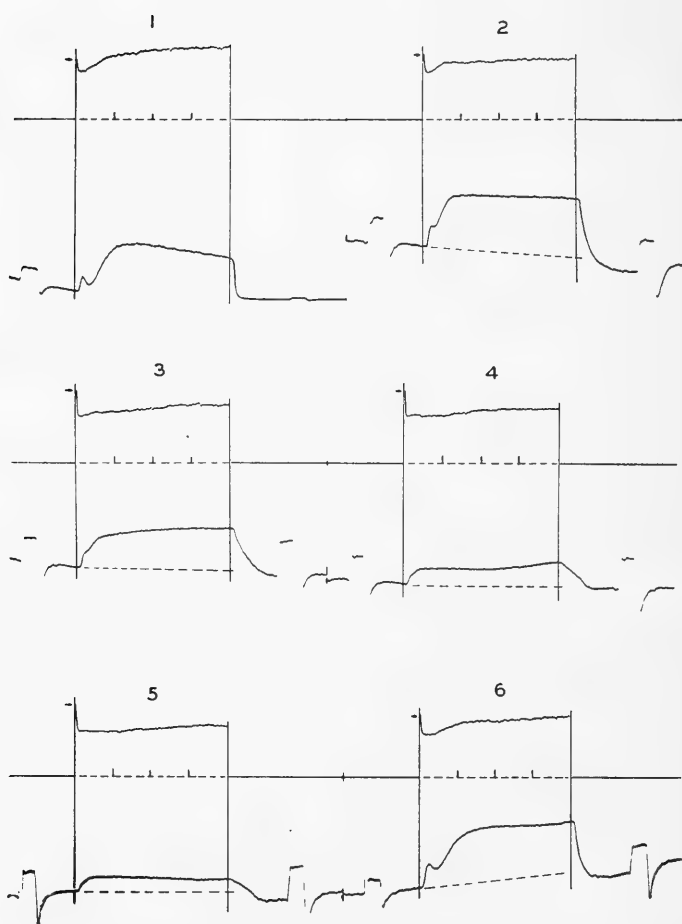
FIG. 10.—The induction behavior in high light of *Chlorella* grown in 0.03 percent carbon dioxide. The effect of carbon dioxide pressure. Each record taken after 5 minutes light in 0.03 percent carbon dioxide, 10 minutes dark with the carbon dioxide pressure specified.

1. In 0.03 percent carbon dioxide.
2. In 0.008 percent carbon dioxide.
3. In 0.003 percent carbon dioxide.
4. In 0.0003 percent carbon dioxide.
5. In zero carbon dioxide.
6. In 0.03 percent carbon dioxide (repeat of curve 1).

the period in high light is greater than the rate measured before illumination—as has been previously pointed out in the literature (cf. Emerson and Lewis, 1939).

In order to determine accurately the course of fluorescence intensity in the first seconds of illumination a few experiments have been made with a very fast galvanometer.[6] Three of these are shown in figure 11. The recording drum was speeded up to give these
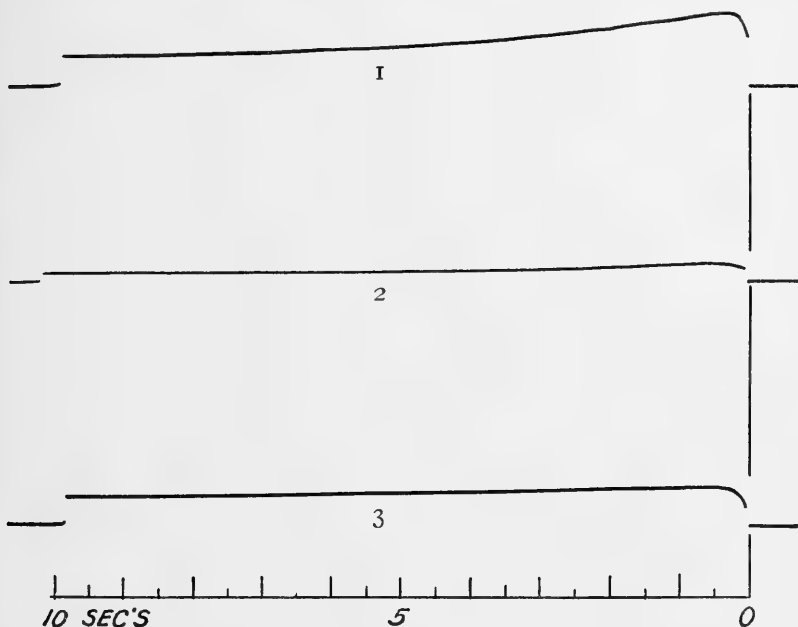
Fig. 11.—The fluorescence behavior of wheat and *Chlorella* in air during the first 10 seconds of illumination.

1. *Chlorella* in high light.
2. *Chlorella* in low light.
3. Wheat in high light.

records, which are reproduced nearly full size. For curve 1 the photocell was placed immediately in back of a suspension of *Chlorella* illuminated with full intensity (60×10^4 ergs/cm.^{2}/sec.). These conditions were duplicated in curve 2 except that the light intensity was cut in half. (The galvanometer sensitivity decreased between these two records owing to a drop in the battery current actuating the field electromagnet, so that the curves cannot be compared

<hr>

[6] Kipp and Zonen "torsion string" galvanometer with electromagnet, 1/100-second period. Loaned by the Department of Terrestrial Magnetism, Carnegie Institution of Washington, courtesy of Dr. M. A. Tuve.

directly as to ordinate height.) Curve 3 was obtained with a layer of attached wheat leaves, one leaf thick, placed in front of the photocell. Further experiments along this line are now in progress.

DISCUSSION

The induction curves for carbon dioxide assimilation of *Sticho-coccus bacillaris* obtained by Aufdemgarten (1939a, 1939b) [7] have been essentially duplicated by our curves for *Chlorella* (figs. 8, 9, 10). His observations on the effects of different nutrient media on the initial maximum in the induction curves are being further investigated in this laboratory. The curves for carbon dioxide assimilation by wheat are consistent with those reported in previous papers (McAlister, 1937, 1939). Changes in technique (constant-flow method, increased sensitivity, and continuous recording) have made it possible to observe two effects not apparent before: 1, a rapid initial uptake of carbon dioxide (fig. 3, curves 1 and 2), and 2, a secondary depression in the rate of carbon dioxide uptake under high concentrations of carbon dioxide (figs. 4 and 5).

Our fluorescence curves for wheat are in almost complete agreement with those obtained by Franck and Wood (1936) on various excised leaves (cf. fig. 1, curves 1 and 2, etc.). Their observation of a rapid initial rise followed by a slower increase to the maximum is duplicated by our experiments using a very fast galvanometer (fig. 11).

Comparison of our fluorescence curves with those of other workers is more difficult owing to the different conditions employed. Kautsky and Marx (1937) obtained for various excised leaves a smoothly rising fluorescence curve approaching a maximum in 3.4 seconds. Their data could be fitted to a straight line by plotting the logarithm of the "fluorescence quenching" against time. In later work from the same laboratory Kautsky and Hormuth (1937) reported fluorescence curves followed during the first 50 seconds of illumination. Although these show a quick rise followed by a slower decay, the magnitudes of the changes involved are much smaller than those obtained by Franck and Wood and by us. These differences can be accounted for, at least in part, by the fact that Kautsky used as the exciting source ultraviolet radiation of probably rather low intensity.

---

[7] It is interesting to note here that the minimum in photosynthesis in intermittent light of about 1-minute intervals reported by McAlister (1937) for wheat has been confirmed by Aufdemgarten (1939a) for both *Hormidium* and *Stichococcus*.

In our studies over a wide range of intensities it is apparent that at low light the proportionate changes in fluorescence intensity are small.

The fluorescence curves obtained by Wassink and Katz (1939) for *Chlorella vulgaris* are also not directly comparable with ours because of the very low light intensities employed. Their highest light (1.9×10^4 ergs/cm.²/sec.) was only about 1/25 of the intensity used in most of our experiments (as in figs. 8, 9, and 10). Their fluorescence curves show a rapid initial rise, followed by a slower rise to a maximum reached in 2 or 3 seconds; a decrease to a minimum at about 5 seconds; a rise to a second maximum at about 20 seconds; and a gradual decay continuing for several minutes. As in the case of Kautsky and Hormuth, the variations observed were proportionately small. Our equipment does not permit us to work effectively at light intensities as low as theirs. However, several of our curves obtained at lower intensities (ca. 10^5 ergs/cm.²/sec.) show some similarity. Curve 5 of figure 1 is very similar to their curves except for the absence of their first maximum; curve 9 of figure 9 is also similar to their curves except for their final decay. Most of the work of Wassink and Katz was devoted to a study of the various phases of the fluorescence curve as functions of temperature, light intensity, and oxygen pressure on cells in which photosynthesis was totally inhibited by cyanide. Such a treatment completely prevents the final decay in fluorescence as clearly shown by their figure 4 (p. 153). Similar experiments have not yet been tried in this laboratory.

Our exploratory data make it clear that a wide range of induction phenomena is exhibited by *Chlorella* and by wheat under various conditions of the plants and their environment. More intensive and quantitative studies now being undertaken are necessary to make clear the complex interplay between the various external and internal factors and their effects on the induction behavior. This discussion will therefore be chiefly phenomenological, considering the relationships of the various observed effects rather than the mechanism by which they are brought about.

INTERPRETATION OF INDUCTION CURVES

The induction curves must first be examined in order to separate instrumental effects from the true plant behavior. The fluorescence curves obtained with the fast galvanometer (period 1/100 second) may be considered very close to the true course of the fluorescence intensity, since the time lag in recording is here very small (fig. 11).

The galvanometer used in the rest of the experiments (figs. 1 to 10) had a period of 1.2 seconds, and this slight lag must therefore be considered in interpreting the fluorescence curves. The recording of the rate of carbon dioxide assimilation is not nearly so rapid. Time is required for the gas stream to pass from the plant chamber to the absorption cell, for the thermocouple response, and for the response of the primary and secondary galvanometers. Fortunately these time lags are not entirely additive. However, there is in addition an integration or "smearing out" of the response. For instance the volume of air in the absorption cell at any instant represents a finite time period of the plant's activity. The galvanometer system may be thought of as responding in overlapping units of time of about 4 seconds each. During the quick initial "gulp" of carbon dioxide (curves 1 and 2 of fig. 3) the peak change in carbon dioxide passes through the absorption cell in much less than 4 seconds. The initial movement of the galvanometer is therefore at least partially a ballistic response with a correspondingly reduced sensitivity and shortened time of indication during this important part of the curve.

A number of the curves shown above have been redrawn in order to eliminate as far as possible the instrumental lag in the recording of the rate of carbon dioxide assimilation. This has been done by making tracings of the original curves and moving the carbon dioxide curve to the left a distance equivalent to the time of transit between the plant chamber and the absorption cell. The curves are also corrected for the decreased sensitivity at higher carbon dioxide concentration which is characteristic of the spectrographic method. In addition a broken line ($-\cdot-\cdot-$) has been added to show the probable course of carbon dioxide assimilation in the plant which would give the recorded curve. This is appreciably different from the recorded curve only during the rapid changes of the first 10 seconds of illumination. The fluorescence curves have not been altered since they are reasonably accurate except for the first 2 or 3 seconds.

Perhaps the simplest type of induction behavior is that exhibited by wheat at low light intensity (fig. 1, curve 5) or following a very short dark rest (fig. 1, curves 6 and 7). These curves approximate linear behavior, i.e., induction effects are here approaching a minimum. It was under light intensities even lower than those in curve 5 of figure 1 that the fluorescence curves of Wassink and Katz and of Kautsky and Hormuth were obtained. It is possible that with greater resolution in our recording apparatus similar effects might be observed here. In any case these effects must be small compared to those obtained at higher intensities.

Figure 12 illustrates the behavior of wheat under high light intensities. The simpler case is shown in curve A obtained under low oxygen pressure. Here there is a strictly inverse relationship between the rate of carbon dioxide assimilation and the intensity of fluorescence. (However, the almost perfect mirror-image relationship of the two curves is purely fortuitous as to ordinate height since both intensity of fluorescence and rate of carbon dioxide assimilation are recorded in arbitrary and independently chosen units. This fact must be borne in mind in the examination of all the curves.) This inverse relationship is one which would be expected if it were assumed that the intensity of fluorescence is always a constant fraction of that part of the energy absorbed by chlorophyll which is not taken up by photochemical mechanisms. Although we have no factual basis for such an assumption, we shall adopt this point of view since it will simplify the discussion without greatly limiting its generality.

On the other hand the induction in air (20 percent oxygen) is more complex and has led us to superimpose the curves in low oxygen as broken lines (-----) for comparison in curve B. Let us assume that the broken line (behavior in low oxygen) represents an approach to an idealized case in which a strictly inverse relationship exists between rate of carbon dioxide assimilation and intensity of fluorescence. The hatched area between the lines would therefore represent the extent of a reaction which decreases both the intensity of fluorescence and rate of carbon dioxide assimilation. Since this reaction is associated with increased oxygen pressure it seems most logical to consider it a photooxidation, sensitized by chlorophyll, which (like photosynthesis) cuts down the intensity of fluorescence, but which also cuts down the rate of carbon dioxide assimilation by producing carbon dioxide or some intermediate which can be used in place of carbon dioxide in photosynthesis.

The essential point involved in the consideration of figure 12, B, is that for wheat in normal air there are two types of reaction affecting the induction curve of carbon dioxide assimilation. In one of these the rate of carbon dioxide uptake and intensity of fluorescence are related inversely; in the other, directly. This point makes no implications as to the nature of the two processes.

Several other cases of induction behavior are examined in figures 13 and 14. The same conventions have been used in presenting these curves as in figure 12 except that here we have no experimentally determined "ideal" curves for comparison. The drawn-in broken lines (-----) have been arbitrarily located so as to give an inverse
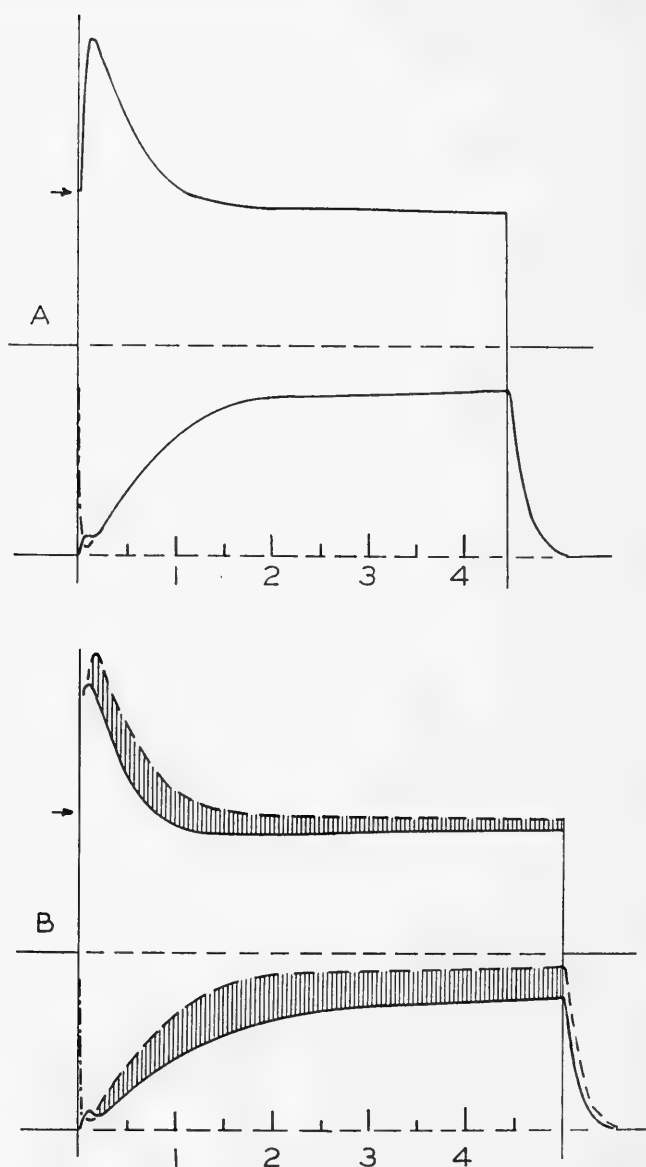
FIG. 12.—Induction behavior of wheat in low (A) and in normal (B) oxygen pressure. In 0.03 percent carbon dioxide, high light, and after 30-minute dark rests. The curves are derived from 2 and 1 of fig. 3.

relationship between the fluorescence and carbon dioxide curves. For instance the broken line superimposed on the fluorescence curve was first drawn so that no intensity less than the final value is reached. A broken line was then superimposed on the carbon dioxide curve so that the indicated rate of uptake always bears an inverse relation to the fluorescence intensity. The enclosed hatched areas therefore represent the minimum extent of reactions bearing a direct relationship to fluorescence.

In the case of wheat in high carbon dioxide (fig. 13, A) it is clear that a reaction takes place during the time of the minimum in fluorescence which involves a direct carbon dioxide-fluorescence relationship. For the rise in fluorescence following the minimum is accompanied by an increase in the rate of carbon dioxide assimilation. On the other hand, the inverse relationship between the second maximum in fluorescence and the second minimum in carbon dioxide assimilation is perfectly clear. This relationship is further borne out in the series of curves of figure 5. Here the second maximum in fluorescence and the second minimum in carbon dioxide assimilation are seen to be similarly affected by progressive changes in carbon dioxide concentration. A certain similarity to this behavior of wheat may be shown by *Chlorella* (fig. 13, B) although the first minimum in fluorescence is less marked and the second maximum is much smaller and more drawn out.

The peculiar behavior of *Chlorella* grown in air is marked by the predominance of a direct relation between carbon dioxide assimilation and fluorescence. In figure 14, A, the broken lines have been drawn arbitrarily straight across and parallel to the base lines. This is another case in which fluorescence data are of direct aid in interpreting the carbon dioxide assimilation curves. By itself, such a carbon dioxide assimilation curve may be interpreted in either of two ways: 1, photosynthesis starts out with a sudden "gulp" of carbon dioxide, then slows, and finally builds up to a steady rate; or 2, photosynthesis starts off at the maximum rate, but a carbon-dioxide-producing reaction occurs for a short period, causing a minimum in the assimilation curve. The fluorescence data reject the first interpretation.

A number of cases have been observed in which the induction in wheat approaches that of *Chlorella* grown in air. One of these is illustrated in figure 14, B. Here a distinct minimum in fluorescence is accompanied by a small but obviously correlated inflection in the assimilation curve. The importance of the "intermediate" cases such as figures 13, B, and 14, B, is that they deny the existence of any real
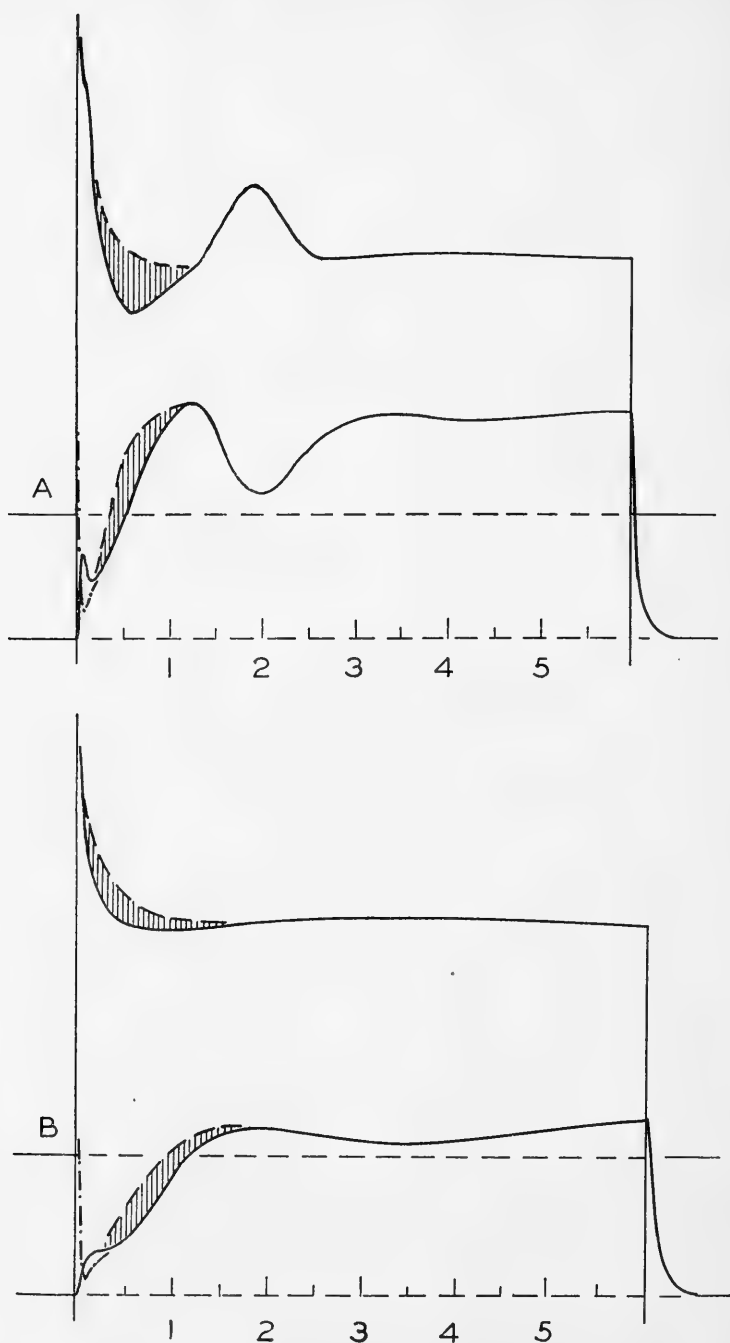
Fig. 13.—Induction behavior in 0.24 percent carbon dioxide and high light of wheat after 10 minutes dark rest (A) and of *Chlorella* grown in 4 percent carbon dioxide after 20 minutes dark rest (B). The curves are derived from 1 of fig. 5 and 1 of fig. 8 respectively. For convenience the ordinate scale for rate of carbon dioxide uptake in A has been reduced to ½.

differences between the photochemical mechanism in *Chlorella* and in wheat. At first glance the induction phenomena shown by *Chlorella* grown in air (fig. 14, *A*) and wheat (fig. 12, *B*) appear very different. However, the occurrence of intermediate cases makes it clear that
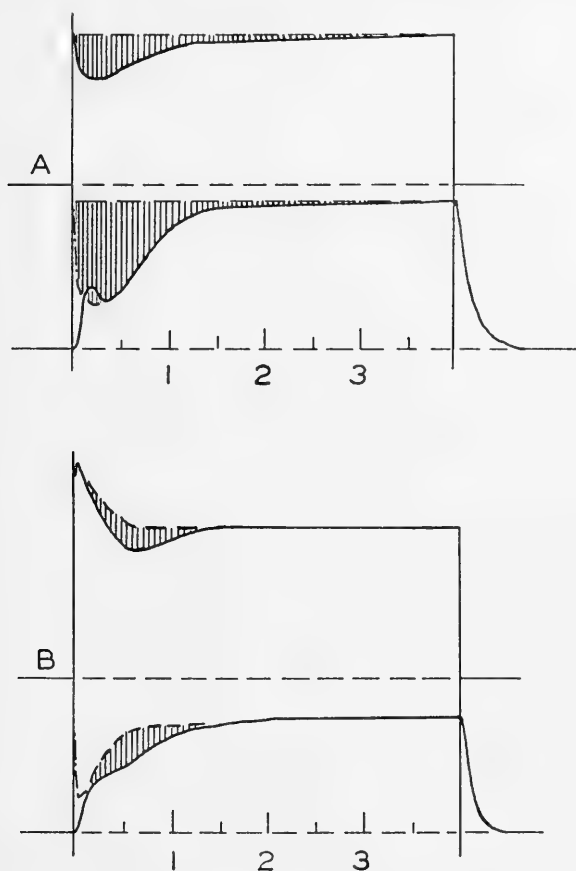
FIG. 14.—Induction behavior in 0.03 percent carbon dioxide and high light after 10 minutes dark rest for *Chlorella* grown in air (A) and for wheat (B). The curves are derived from 6 of fig. 10 and 5 of fig. 3 respectively.

this difference is due merely to the predominance of one or the other of at least two different processes in these extreme cases.

STEADY-STATE RELATIONS

Measurements of the steady-state conditions of fluorescence and rate of carbon dioxide assimilation were made with the hope of ob-

taining additional data which might be of help in the interpretation
of the relationship between fluorescence and photosynthesis shown by
induction studies. Similar studies have been made by Wassink et al.
(1938), who have measured the intensity of fluorescence and rate of
oxygen production under steady-state conditions. They report no
change in the state of fluorescence (i.e., intensity of fluorescence
proportional to incident intensity) in passing from a light-limiting
condition of photosynthesis to light-saturation. Nor was fluorescence
intensity influenced by any of a number of conditions which markedly
affected the rate of photosynthesis (temperature, partial inhibition
by cyanide, oxygen pressure). However, when photosynthesis was
partially inhibited by urethane, the intensity of fluorescence was
clearly raised. In a later paper Wassink and Katz (1939) showed an
increase in intensity of fluorescence due to complete inhibition of
photosynthesis by cyanide. Their highest incident intensity was less
than 2×10^4 ergs/cm.^{2}/sec. Complete saturation was apparently
reached at this intensity in the number 9 carbonate-bicarbonate buffer
of Warburg (1920).

In the present experiments on wheat [8] we find a marked change
in fluorescence in passing from light-limiting to carbon-dioxide-
limiting conditions. This is seen in both figures 15 and 16. Figure 15
shows the rate of carbon dioxide assimilation and intensity of
fluorescence for wheat at 23° C. and 0.03 percent carbon dioxide in
both air and tank nitrogen as a function of incident intensity. For
the two cases in air (duplicate experiments) the intensity of
fluorescence is seen to rise above the initial straight line concurrently
with a marked departure from light-limiting conditions.

Figure 16 exhibits a similar behavior in a comparison of intensity
of fluorescence under 4 percent and 0.03 percent carbon dioxide.
Here, presumably, the wheat was entirely under light-limiting con-
ditions at 4 percent carbon dioxide, but at 0.03 percent carbon
dioxide a carbon dioxide limitation begins at relatively low incident
intensity (cf. fig. 15) and the fluorescence intensity rises above the
initial line.

Warburg (1920) has shown that *Chlorella* in high light and high
carbon dioxide produces oxygen at a considerably greater rate in 2
percent than in 20 percent oxygen. A similar behavior as to carbon
dioxide assimilation in wheat is shown by figure 15. Here under
carbon-dioxide-limiting conditions the rate is 30 percent higher in

---

[8] Similar quantitative experiments on algae have not been feasible with our
present equipment. Such work is anticipated.

0.5 percent than in 20 percent oxygen. As Warburg pointed out, this suggests that the rate of a reaction involving oxygen and opposing photosynthesis is diminished in passing from high to low oxygen, and consequently the rate of carbon dioxide assimilation is increased. The intensity of fluorescence is lower in this experiment in 0.5 percent oxygen than in normal air. However, the
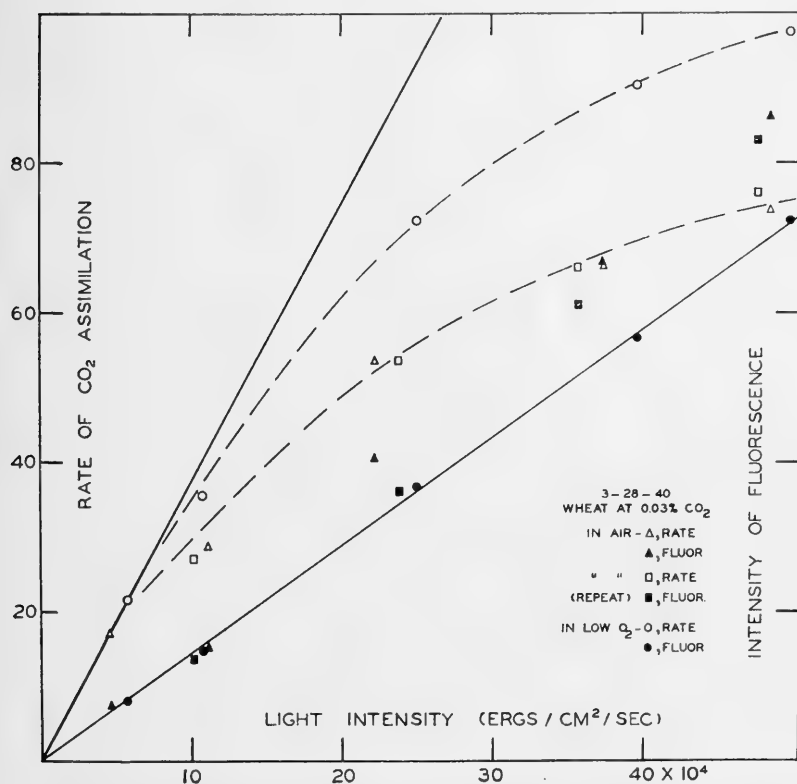
FIG. 15.—Carbon dioxide assimilation and intensity of fluorescence versus incident light intensity. A comparison of low and normal oxygen pressures for wheat at 0.03 per cent carbon dioxide.

intensities of fluorescence in these two cases of 0.5 percent and 20 percent oxygen are reversed in the steady state as compared to their relationship in and immediately following the induction period when the fluorescence is higher for the low oxygen condition (see fig. 12, *B*). Thus the fluorescence data suggest a different possibility, namely, a transition from the situation in the induction period already discussed to a case in the steady state where oxygen is able

to inhibit photosynthesis. Reducing the oxygen pressure then allows a greater rate of photosynthesis and the fluorescence is consequently reduced. Further experiments, wherein the transition from the induction phase to the steady state is followed more closely are
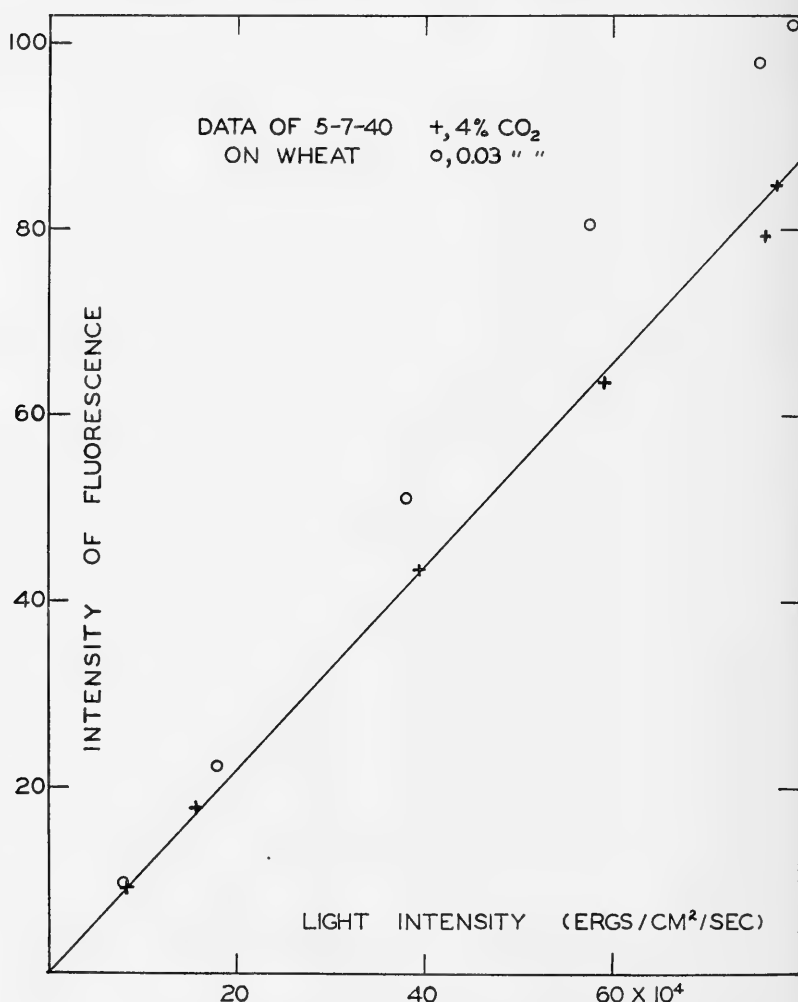
Fig. 16.—Intensity of fluorescence versus incident light intensity for wheat at 4 percent and at 0.03 percent carbon dioxide.

anticipated and should distinguish between these two opposing explanations.

It is interesting to note that this oxygen effect of relatively large proportions occurs under natural growing conditions and hence may

be of importance in studies involving vegetative growth. As yet it has been observed only in wheat, but other plants should be examined to determine the generality of the phenomenon. Because of its magnitude and intimate relationship with photosynthesis it should not be considered as an effect of light on the normal (dark) respiration.[9] Curve 3 of figure 7 indicates, as was previously reported by McAlister (1939), that respiration of wheat in light (in the absence of photosynthesis) is observed to be of the same magnitude as in darkness.

In comparing our data on wheat with those of Wassink et al. (1938) on *Chlorella,* it must be borne in mind that their incident intensities were nearly two orders of magnitude smaller than ours. Although our equipment does not permit accurate work at such low intensities, in this region we likewise find no marked departure from a linear relationship between intensity of fluorescence and incident light intensity. The only marked departure that we do find appears to be due to a carbon dioxide limitation, whereas with the number 9 buffer and the low intensities used, Wassink et al. were not far from light-limiting conditions in most of their experiments. In none of their experiments did they attain a carbon dioxide limitation. Consequently our data are not at great variance with theirs.

The young wheat used in our experiments requires very high intensity to reach light-saturation. In experiments, as yet incomplete, we have used incident intensities as high as 140×10^4 ergs/cm.^{2}/sec., which are twice as high as those of figure 16 and three times the intensity in visible solar radiation. At this highest intensity we have found that carbon dioxide assimilation in 0.4 percent carbon dioxide is still increasing though not at the light-limited rate. In the experiments of Hoover et al. (1933) incident intensities up to about 70×10^4 ergs/cm.^{2}/sec. were used. It is important to point out here that their Mazda radiation was filtered only by a 2.5-mm. layer of saturated copper sulphate solution. Consequently the incident intensities effective in producing photosynthesis in their experiments were from 20 to 30 percent of the values reported. However, their experiments clearly indicate that a very high value for light-saturation is to be expected for young wheat.

THE "DARK PICK-UP" OF CARBON DIOXIDE

A dark pick-up of carbon dioxide is apparent in all the assimilation curves obtained with the continuous-flow method. That it is greater than the instrumental lag is seen when it is compared to this lag,

---

[9] See also Gaffron (1940).

as for example in figure 1, curve 4, figure 5, curves 4 and 6, and figure 8, curves 2, 5, and 8. The sharp dip at the end of these curves (in darkness) represents the sweeping out of the system of a 15-seconds' accumulation of respired carbon dioxide upon resumption of the air flow. This gives a measure of the total instrumental lag in the case of wheat and of the instrumental plus liquid-to-gas diffusion time in the case of *Chlorella* (fig. 8).

A greatly increased time for the dark pick-up is evident when the plants have been in low carbon dioxide concentration during the light period. This is seen in curves 1, 3, 4, and 5 of figure 2, curves 3, 4, and 5 of figure 10, and particularly in curve 2 of figure 7. In this latter case, where the concentration of oxygen was also low, the dark pick-up has a half time of more than 1 minute.

Much more work remains to be done on this dark pick-up, particularly when the present type of experiment is put on a more quantitative basis. The present work with the continuous-flow method has not shown a dark pick-up lasting for 15 or 20 seconds following a high rate of photosynthesis as was previously reported (McAlister, 1939). This discrepancy is being investigated and will be reported on in the near future.

GENERAL DISCUSSION

It has been the purpose of this paper to examine a wide range of induction phenomena rather than to study any one of them in detail. The apparent relationships between these various effects have been pointed out. A correlation between the fluorescence intensity and rate of carbon dioxide uptake has been clearly shown in a number of cases, although this has involved sometimes a direct, and at other times an inverse, relationship.

Induction phenomena have been observed whenever a sudden increase in the rate of photosynthesis was brought about. Particularly significant are the fluorescence curves accompanying sudden changes in carbon dioxide concentration. These show clearly that fluorescence is somehow affected by the rate of photosynthesis. On the other hand it must be pointed out that changes in intensity of fluorescence have occasionally been observed without accompanying deviations in the rate of carbon dioxide uptake (e.g., curve 4 of fig. 2, and curve 3 of fig. 9, and others not shown).

Our data make it clear that the induction of photosynthesis is not a single or simple process. It is conceivable that during this period three types of reactions are proceeding toward the steady-state condition: 1, photosynthesis, involving the reduction of carbon dioxide;

2, photooxidation, an oxidation of certain more stable intermediates or products of photosynthesis, sensitized by chlorophyll; and 3, oxidation, a direct burning of unstable intermediates of photosynthesis. Of these the first two are dependent, the third independent, of energy transfer from activated chlorophyll.

The simple viewpoint which we have taken of the transfer of energy from activated chlorophyll is that such energy may be: 1, contributed to a photochemical process; 2, re-emitted as fluorescence; or 3, lost as heat. It is thus possible that the intensity of fluorescence may be influenced by either photosynthesis or photooxidation or by both processes simultaneously. Our data show that some such relationship does exist, but the details of the relation are obscured by our lack of knowledge of the mechanism of the quenching of fluorescence.

Another line of evidence comes from the dependence of the induction effects on the length of the previous dark rest. This well-established phenomenon may be accounted for by either of two alternate hypotheses: 1, Some material, formed by respiration, gradually accumulates (up to a maximum level) in the dark. In its subsequent photooxidation in light, transient intermediates are formed which somehow aid in the emission of fluorescence. 2, Some intermediate or product of photosynthesis, formed in light, inhibits fluorescence and increases the rate of photosynthesis. In the dark the concentration of this substance progressively decreases.

Either of these two hypotheses can be made to account for the induction in both carbon dioxide uptake and fluorescence of wheat in 0.03 percent carbon dioxide (fig. 12). However, the implications of the two hypotheses are very different. The first [10] postulates that photosynthesis starts out immediately at about the level of the steady rate. The induction in carbon dioxide uptake is due to the carbon dioxide (or carbon-dioxide-sparing substance) produced by the initial photooxidation. This also means that there is a direct relationship between rate of carbon dioxide *production* and intensity of fluorescence, i.e., an *inverse* relationship between rate of carbon dioxide *uptake* and intensity of fluorescence.

The second hypothesis, on the other hand (as suggested above, p. 23), supposes that the rates of both photosynthesis and photooxidation bear an inverse relationship to the intensity of fluorescence. There is an initial "gulp" of carbon dioxide and momentary quenching of fluorescence which corresponds to the amount of "intermediate"

---

[10] Suggested to us by Dr. James Franck.

adsorbed in the neighborhood of the chlorophyll and not destroyed in the dark. Thereafter the concentration of this intermediate first decreases until its rate of formation equals its rate of utilization, then it slowly increases to the steady-state value. Correspondingly, the fluorescence rises abruptly to a maximum and then slowly decays, while the rate of carbon dioxide assimilation falls sharply to a minimum and then rises gradually to the equilibrium rate.

Neither of these hypotheses will account for all the data obtained. The first is certainly inconsistent with the burst of fluorescence caused by a suddenly increased carbon dioxide concentration (curves 3 and 4 of fig. 6) and makes difficult any interpretation of the several observed cases in which carbon dioxide and fluorescence are directly related (figs. 13 and 14). The second does not explain the inverse relation between the second carbon dioxide minimum and the second fluorescence maximum found in wheat at high carbon dioxide concentration (fig. 13, A). However, because it seemed more consistent with the other data, we have taken this viewpoint as a basis for discussion.

From this second viewpoint the induction shown by wheat in 0.03 percent carbon dioxide in nitrogen is chiefly the building up of the rate of photosynthesis accompanied by a decay in fluorescence.[11] In air a photooxidation occurs as a secondary process, prolonging the induction in carbon dioxide uptake.

In *Chlorella* either one or the other of these two processes may be made to predominate. This alga quickly adapts itself to environmental conditions. Cells grown in 4 percent carbon dioxide show, when first studied, an induction generally similar to that of wheat (as fig. 13, B). After a few hours of light in 0.03 percent carbon dioxide the fluorescence curve develops a noticeable minimum during the induction period. After 24 hours in 0.03 percent carbon dioxide the induction behavior has changed completely to that shown by cells which have never been in high carbon dioxide (as fig. 14, A). During this time the secondary photooxidation progressively attains a more important role in the induction behavior until all other effects seem to be obscured.[12]

---

[11] This decay may also be brought about in zero carbon dioxide if oxygen is present (curves 4 and 6 of fig. 3). This may be interpreted as due to the opposing effects of photosynthesis and photooxidation, for which the carbon dioxide uptake curve is the net result.

[12] This experience may be related to Aufdemgarten's observation (1939b) that the minimum in the induction curve of carbon dioxide uptake is dependent on the composition of the nutrient media used.

SUMMARY

Simultaneous measurements of intensity of fluorescence and rate of carbon dioxide assimilation during and following the induction period in wheat and in *Chlorella* are reported. While these observations are to be regarded as exploratory and preliminary, they permit the following conclusions:

1. Any sudden change in conditions of illumination or of carbon dioxide concentration that produces a large increase in the rate of photosynthesis also gives rise to a "burst" in the intensity of fluorescence. When this change is from darkness to high light, the burst of fluorescence produced can be resolved into three parts, as was previously shown by Franck and Wood. The intensity of fluorescence rises instantly (less than 0.01 second) to a height about equal to the final equilibrium value, then more slowly (in about 1 second) rises two or three times higher to a maximum which is followed by a decay (lasting about 1 minute) to the equilibrium value. The simultaneously observed rate of carbon dioxide assimilation follows a curve that is inversely related to the changes in fluorescence. When the recorded curve is corrected for instrumental effects it is apparent that the rate of carbon dioxide uptake starts at a value at least as high as the equilibrium rate, then quickly drops to a low minimum (but not negative) value, followed by a rise asymptotically approaching the final rate. At low oxygen pressures (less than $\frac{1}{2}$ percent) the curves of fluorescence and rate of carbon dioxide uptake are almost exact mirror images of each other (as to time).

2. The changes in rate of carbon dioxide assimilation observed in the induction period of wheat under normal air conditions (20 percent oxygen and 0.03 percent carbon dioxide) are caused by two processes, of which one exhibits an inverse relation to intensity of fluorescence and the other is directly related. The dependence of this second type on oxygen pressure and the observation of a greater rate of carbon dioxide uptake under low oxygen pressures suggests that this second type of reaction is a photooxidation.

3. In *Chlorella* the induction behavior is greatly influenced by the previous conditions of culture. Cells grown in high carbon dioxide show a behavior quite comparable to that of wheat. In the induction shown by cells acclimated to low carbon dioxide, the photooxidation type of reaction predominates to such an extent that pronounced minima are produced in both the fluorescence and carbon dioxide uptake curves.

4. Under carbon dioxide concentrations greater than that of normal air the induction phenomenon in wheat is complicated by a second maximum in fluorescence occurring after about 1-minute illumination. At the same time a minimum in rate of carbon dioxide uptake is observed which clearly bears an inverse relationship to this second maximum of fluorescence.

5. Curves relating intensity of fluorescence and rate of carbon dioxide uptake to incident intensity have been obtained from measurements made under steady-state conditions following the induction period. These show a marked change in fluorescence in passing from light-limiting to carbon-dioxide-limiting conditions. The intensity of fluorescence rises above the initial straight line concurrently with a marked departure from light-limiting conditions.

The rate of carbon dioxide assimilation in wheat in high light and 0.03 percent carbon dioxide is 30 to 50 percent higher in 0.5 percent than in 20 percent oxygen. This suggests that for young wheat a reaction of large proportions opposing photosynthesis is always depressing the rate of carbon dioxide assimilation under natural growing conditions.

LITERATURE CITED

AUFDEMGARTEN, H.
  1939a. Zur Kenntnis der sogenannten Induktionsvorgänge bei der Kohlensäureassimilation. Planta, vol. 29, pp. 643-678.
  1939b. Weitere Untersuchungen mit dem Gaswechselscheiber über die Kohlensäureassimilation. Planta, vol. 30, pp. 343-352.
EMERSON, R., and LEWIS, C. M.
  1939. Factors influencing the efficiency of photosynthesis. Amer. Journ. Bot., vol. 26, pp. 808-822.
FRANCK, J., and HERZFELD, K. F.
  1937. An attempted theory of photosynthesis. Journ. Chem. Phys., vol. 5, pp. 237-251.
FRANCK, J., and WOOD, R. W.
  1936. Fluorescence of chlorophyll in its relation to photochemical processes in plants and organic solutions. Journ. Chem. Phys., vol. 4, pp. 551-560.
GAFFRON, H.
  1940. Studies on the induction period of photosynthesis and light respiration in green algae. Amer. Journ. Bot., vol. 27, pp. 204-216.
HOAGLAND, D. R., and ARNON, D. I.
  1938. The water-culture method for growing plants without soil. Univ. California Agr. Exp. Stat. Circ. 347, pp. 1-39. Also in Ann. Rep. Smithsonian Inst. for 1938, pp. 461-488.
HOOVER, W. H., JOHNSTON, E. S., and BRACKETT, F. S.
  1933. Carbon dioxide assimilation in a higher plant. Smithsonian Misc. Coll., vol. 87, No. 16, pp. 16-17.

KAUTSKY, H., and HORMUTH, R.
   1937. Die Abhandigkeit des Verlaufs der Fluoreszenzkurven grüner
      Blätter vom Sauerstoffdruck. Biochem. Zeitschr., vol. 291, pp. 285-
      311.
KAUTSKY, H., and MARX, A.
   1937. Photographische Registrierung und Auswertung der Fluoreszenzin-
      tensität grüner Blätter. Biochem. Zeitschr., vol. 290, pp. 248-260.
McALISTER, E. D.
   1937. Time course of photosynthesis for a higher plant. Smithsonian Misc.
      Coll., vol. 95, No. 24, pp. 1-17.
   1939. The chlorophyll-carbon dioxide ratio during photosynthesis. Journ.
      Gen. Physiol., vol. 22, pp. 613-636.
ORNSTEIN, L. S., WASSINK, E. C., REMAN, G. H., and VERMEULEN, D.
   1938. Theoretical considerations concerning the relation between chloro-
      phyll fluorescence and photosynthesis in green plant cells. Enzymol.,
      vol. 5, pp. 110-118.
VERMEULEN, D., WASSINK, E. C., and REMAN, G. H.
   1937. On the fluorescence of photosynthesizing cells. Enzymol., vol. 4,
      pp. 254-268.
WARBURG, O.
   1920. Über die Geschwindigkeit der photochemischen Kohlensaurezer-
      setzung in lebenden Zellen. II. Biochem. Zeitschr., vol. 103, p. 188.
WASSINK, E. C., and KATZ, E.
   1939. The initial changes of chlorophyll-fluorescence in *Chlorella*. En-
      zymol., vol. 5, pp. 145-172.
WASSINK, E. C., VERMEULEN, D., REMAN, G. H., and KATZ, E.
   1938. On the relation between fluorescence and assimilation in photo-
      synthesizing cells. Enzymol., vol. 5, pp. 100-109.

A SYSTEMATIC CLASSIFICATION FOR THE BIRDS
OF THE WORLD

BY
ALEXANDER WETMORE
Assistant Secretary, Smithsonian Institution

A SYSTEMATIC CLASSIFICATION FOR THE BIRDS OF THE WORLD

BY
ALEXANDER WETMORE
Assistant Secretary, Smithsonian Institution

A SYSTEMATIC CLASSIFICATION FOR THE BIRDS OF THE WORLD

By ALEXANDER WETMORE

Assistant Secretary, Smithsonian Institution

The steady demand for a systematic arrangement for the birds of the world has exhausted the edition of the revision issued in 1934 [1] so that the classification is reprinted herewith, with relatively few changes based on subsequent findings.

The order Caenagnathiformes, family Caenagnathidae, has been included as a new group under the superorder Palaeognathae. *Caenagnathus collinsi,* the species on which this proposal is based, is known from a nearly complete mandible described in 1940 by Raymond M. Sternberg, from the Upper Cretaceous of Alberta, Canada. It is not absolutely certain that this is avian, but it is accepted as a bird pending further information.

A separate family, the Baptornithidae, has been listed for the Upper Cretaceous *Baptornis advenus,* since on a review of what is known this seems warranted. *Apatornis celer* also is placed in a distinct family, the Apatornithidae.

Another fossil family, the Paranyrocidae, has been included for a curious fossil Anseriform described by A. H. Miller and L. V. Compton from the Rosebud formation of the Lower Miocene of South Dakota.

The fish-hawks, or ospreys, are given under a separate family, the Pandionidae, placed in the superfamily Falconoidea. The peculiarities of the ospreys, long recognized, have been established definitely through recent researches by L. V. Compton, who has in fact proposed to transfer *Pandion* to the suborder Cathartae. The present writer feels, however, that such action is not warranted under present information, as he considers the resemblances to the New World vultures alleged to be due more probably to convergence than to actual genetic relationship. The Cathartae seem to stand quite alone.

During the preparation of volume 3 of J. L. Peters' Check-list of Birds of the World (published in 1937) Mr. Peters and I considered

---

[1] Wetmore, A., A systematic classification for the birds of the World, revised and amended. Smithsonian Misc. Coll., vol. 89, No. 13, April 23, 1934, pp. 1-11.

again the characters of the various groups of parrotlike species with the result that it did not seem possible to give the lories more than subfamily rank. This extends the limits of the family Psittacidae to coincide with those of the order.

The only other changes are the use of Acanthisittidae for Xenicidae, and of Tersinidae for Procniatidae, because of current nomenclatural decisions.

It may be repeated that arrangement of the various passeriform families in linear sequence, particularly in the suborder Passeres, or song birds, is a matter of difficulty, since the problem is one of three-dimensional relationship that must be represented in a single column. Obviously, the treatment in some instances must be arbitrary and subject therefore to individual opinion. Without going too deeply into the matter, it has been suggested that such specialized families of the fringilline series as the Coerebidae and Icteridae should come at the end of the list in place of the Fringillidae. In considering the evolution of this assemblage, it appears to me that the more specialized families have been derived by modification from the Fringillidae, while the latter family has retained and carried along more general characters from which further specialization may take place, if with civilized man's disturbance of natural conditions on our earth continuation of evolution among birds is possible. The Coerebidae and Icteridae, to take these as examples, are specialized branches that are assumed now to be more or less static and fixed and therefore should stand at the side. The Fringillidae, representing the central group through which further progress may be expected, should be placed as the terminus of the central stem at the end.

Class Aves, Birds.
  Subclass Archaeornithes, Ancestral Birds.
      Order Archaeopterygiformes, *Archaeopteryx, Archaeornis.*
          Family Archaeopterygidae, *Archaeopteryx, Archaeornis* (fossil).
  Subclass Neornithes, True Birds.
    Superorder Odontognathae, New World Toothed Birds.
      Order Hesperornithiformes, Hesperornithes.
          Family Hesperornithidae, *Hesperornis, Hargeria* (fossil).
             Enaliornithidae,[2] *Enaliornis* (fossil).
             Baptornithidae, *Baptornis* (fossil).
      Order Ichthyornithiformes, Ichthyornithes.
          Family Ichthyornithidae, *Ichthyornis* (fossil).
             Apatornithidae, *Apatornis.*
    Superorder Palaeognathae, Struthious Birds and Allies.
      Order Caenagnathiformes, Caenagnathus.
          Family Caenagnathidae, *Caenagnathus*[3] (fossil).
      Order Struthioniformes, Ostriches.
          Family Struthionidae, Ostriches.
      Order Rheiformes, Rheas.
          Family Rheidae, Rheas.
      Order Casuariiformes, Cassowaries, Emus.
          Family Casuariidae, Cassowaries.
             Dromiceidae, Emus.
             Dromornithidae, *Dromornis* (fossil).
      Order Dinornithiformes, Moas.
          Family Dinornithidae, Moas (fossil and extinct).
             Anomalopterygidae, *Anomalopteryx, Emeus,* and Allies (fossil and extinct).
      Order Aepyornithiformes, Elephant-birds.
          Family Aepyornithidae, *Aepyornis* (fossil and extinct).
      Order Apterygiformes, Kiwis.
          Family Apterygidae, Kiwis.
      Order Tinamiformes, Tinamous.
          Family Tinamidae, Tinamous.

---

[2] Position provisional. Lambrecht, Handbuch der Palaeornithologie, 1933, pp. 255-261, unites the Baptornithidae with this group, which he considers closely related to the loons and grebes.

[3] This interesting genus is listed tentatively in the above superorder since its affinities are not as yet fully known.

Superorder Impennes, Penguins.
    Order Sphenisciformes, Penguins.
        Family Spheniscidae, Penguins.
            Cladornithidae, *Cladornis* (fossil).
Superorder Neognathae, Typical Birds.
    Order Gaviiformes, Loons.
        Family Gaviidae, Loons.
    Order Colymbiformes, Grebes.
        Family Colymbidae, Grebes.
    Order Procellariiformes, Albatrosses, Shearwaters, Petrels,
            and Allies.
        Family Diomedeidae, Albatrosses.
            Procellariidae, Shearwaters, Fulmars.
            Hydrobatidae, Storm Petrels.
            Pelecanoididae, Diving Petrels.
    Order Pelecaniformes, Tropic-birds, Pelicans, Frigate-birds,
            and Allies.
      Suborder Phaëthontes, Tropic-birds.
        Family Phaëthontidae, Tropic-birds.
      Suborder Pelecani, Pelicans, Boobies, Cormorants, Snake-
            birds.
        Superfamily Pelecanoidea, Pelicans and Allies.
        Family Pelecanidae, Pelicans.
            Cyphornithidae, *Cyphornis, Palaeochenöides*
              (fossil).
        Superfamily Suloidea, Boobies, Cormorants, and Allies.
        Family Pelagornithidae, *Pelagornis* (fossil).
            Sulidae, Boobies, Gannets.
            Elopterygidae, *Elopteryx, Eostega, Actiornis*
              (fossil).
            Phalacrocoracidae, Cormorants.
            Anhingidae, Snake-birds.
      Suborder Fregatae, Frigate-birds.
        Family Fregatidae, Frigate-birds.
      Suborder Odontopteryges, *Odontopteryx, Pseudodontornis*
            (fossil).
        Family Odontopterygidae, *Odontopteryx* (fossil).
            Pseudodontornithidae,[4] *Pseudodontornis* (fos-
              sil).

---

[4] Position not certain; see Lambrecht, Handbuch der Palaeornithologie, 1933, pp. 305-308.

Order Ciconiiformes, Herons, Storks, and Allies.
  Suborder Ardeae, Herons, Bitterns.
      Family Ardeidae, Herons, Bitterns.
          Cochleariidae, Boat-billed Herons.
  Suborder Balaenicipites, Whale-headed Storks.
      Family Balaenicipitidae, Whale-headed Storks.
  Suborder Ciconiae, Storks, Ibises, Spoonbills.
    Superfamily Scopoidea, Hammerheads.
      Family Scopidae, Hammerheads.
    Superfamily Ciconioidea, Storks.
      Family Ciconiidae, Storks, Jabirus.
    Superfamily Threskiornithoidea, Ibises.
      Family Threskiornithidae, Ibises, Spoonbills.
  Suborder Phoenicopteri, Flamingos.
      Family Agnopteridae, *Agnopterus* (fossil).
          Scaniornithidae, *Scaniornis, Parascaniornis* (fossil).
          Phoenicopteridae, Flamingos.
Order Anseriformes, Screamers, Ducks, Geese, Swans.
  Suborder Anhimae, Screamers.
      Family Anhimidae, Screamers.
  Suborder Anseres, Ducks, Geese, Swans.
      Family Paranyrocidae, *Paranyroca* (fossil).
          Anatidae, Ducks, Geese, Swans.
Order Falconiformes, Vultures, Hawks, Falcons.
  Suborder Cathartae, New World Vultures.
      Family Cathartidae, New World Vultures.
          Teratornithidae, *Teratornis, Cathartornis* (fossil).
  Suborder Falcones, Secretary-birds, Hawks, Falcons.
    Superfamily Sagittarioidea, Secretary-birds.
      Family Sagittariidae, Secretary-birds.
    Superfamily Falconoidea, Hawks, Falcons, and Allies.
      Family Accipitridae, Hawks, Old World Vultures, Harriers.
          Pandionidae, Ospreys.
          Falconidae, Falcons, Caracaras.
Order Galliformes, Megapodes, Curassows, Pheasants, Hoatzins.
  Suborder Galli, Megapodes, Curassows, Grouse, Pheasants.
    Superfamily Cracoidea, Megapodes, Curassows.
      Family Megapodiidae, Megapodes.
          Gallinuloididae, *Gallinuloides* (fossil).
          Cracidae, Curassows, Guans, Chachalacas.

Superfamily Phasianoidea, Grouse, Pheasants, Turkeys.
    Family Tetraonidae, Grouse.
            Phasianidae,[5] Quails, Pheasants, Peacocks.
            Numididae, Guinea-fowl.
            Meleagrididae, Turkeys.
    Suborder Opisthocomi, Hoatzins.
        Family Opisthocomidae, Hoatzins.
Order Gruiformes, Cranes, Rails, and Allies.
    Suborder Mesoenatides, Roatelos, Monias.
        Family Mesoenatidae, Roatelos, Monias.
    Suborder Turnices, Bustard-quails, Hemipodes.
        Family Turnicidae, Bustard-quails.
            Pedionomidae, Collared Hemipodes.
    Suborder Grues, Cranes, Limpkins, Trumpeters, Rails.
        Superfamily Gruoidea, Cranes, Limpkins, Trumpeters.
            Family Geranoididae, *Geranoides* (fossil).
                    Eogruidae, *Eogrus* (fossil).
                    Gruidae, Cranes.
                    Aramidae, Limpkins.
                    Psophiidae, Trumpeters.
        Superfamily Ralloidea, Rails.
            Family Orthocnemidae,[6] *Orthocnemus, Elaphrocnemus*
                    (fossil).
                    Rallidae, Rails, Coots, Gallinules.
    Suborder Heliornithes, Sun-grebes.
        Family Heliornithidae, Sun-grebes.
    Suborder Rhynocheti, Kagus.
        Family Rhynochetidae, Kagus.
    Suborder Eurypygae, Sun-bitterns.
        Family Eurypygidae, Sun-bitterns.
    Suborder Phororhaci, *Phororhacos* and Allies.
        Family Phororhacidae, *Phororhacos, Pelecyornis,* and
                    Allies (fossil).
                    Brontornithidae, *Brontornis, Liornis,* and Allies
                    (fossil).
                    Opisthodactylidae, *Opisthodactylus* (fossil).

---

[5] Includes the quails, formerly recognized as the family Perdicidae.

[6] Position provisional. See Lambrecht, Handbuch der Palaeornithologie, 1933, pp. 490-493.

Suborder Cariamae, Cariamas and Allies.
 Family Bathornithidae, *Bathornis* (fossil).
  Hermosiornithidae, *Hermosiornis, Procariama* (fossil).
  Cariamidae, Cariamas.
Suborder Otides, Bustards.
 Family Otididae, Bustards.
Order Diatrymiformes, *Diatryma, Omorhamphus,* and Allies.
 Family Diatrymidae, *Diatryma* (fossil).
  Gastornithidae, *Gastornis, Remiornis* (fossil).
Order Charadriiformes, Shore-birds, Gulls, Auks.
 Suborder Charadrii, Shore-birds.
 Superfamily Jacanoidea, Jaçanas.
 Family Jacanidae, Jaçanas.
 Superfamily Charadrioidea, Plovers, Sandpipers, and Allies.
 Family Rostratulidae, Painted Snipe.
  Haematopodidae, Oyster-catchers.
  Charadriidae, Plovers, Turnstones, Surf-birds.
  Scolopacidae, Snipe, Woodcock, Sandpipers.
  Recurvirostridae, Avocets, Stilts.
  Presbyornithidae, *Presbyornis* (fossil).
  Phalaropodidae, Phalaropes.
 Superfamily Dromadoidea, Crab-plovers.
 Family Dromadidae, Crab-plovers.
 Superfamily Burhinoidea, Thick-knees.
 Family Burhinidae, Thick-knees.
 Superfamily Glareoloidea, Pratincoles, Coursers.
 Family Glareolidae, Pratincoles, Coursers.
 Superfamily Thinocoroidea, Seed-snipe.
 Family Thinocoridae, Seed-snipe.
 Superfamily Chionoidea, Sheath-bills.
 Family Chionidae, Sheath-bills.
 Suborder Lari, Gulls, Terns, Skimmers.
 Family Stercorariidae, Skuas, Jaegers.
  Laridae, Gulls, Terns.
  Rynchopidae, Skimmers.
 Suborder Alcae, Auks.
 Family Alcidae, Auks, Auklets, Murres.
Order Columbiformes, Sand-grouse, Pigeons, Doves.
 Suborder Pterocletes, Sand-grouse.
 Family Pteroclidae, Sand-grouse.

Suborder Columbae, Pigeons and Doves.
    Family Raphidae, Dodos, Solitaires.
        Columbidae, Pigeons, Doves.
Order Psittaciformes, Lories, Parrots, Macaws.
    Family Psittacidae, Lories, Parrots, Macaws.
Order Cuculiformes, Plantain-eaters, Cuckoos.
    Suborder Musophagi, Plantain-eaters.
        Family Musophagidae, Plantain-eaters.
    Suborder Cuculi, Cuckoos, Roadrunners, Anis.
        Family Cuculidae, Cuckoos, Roadrunners, Anis.
Order Strigiformes, Owls.
    Family Protostrigidae, *Protostrix* (fossil).
        Tytonidae, Barn-owls.
        Strigidae, Owls.
Order Caprimulgiformes, Oil-birds, Goatsuckers.
    Suborder Steatornithes, Oil-birds.
        Family Steatornithidae, Oil-birds.
    Suborder Caprimulgi, Frogmouths, Goatsuckers.
        Family Podargidae, Frogmouths.
        Nyctibiidae, Potoos.
        Aegothelidae, Owlet-frogmouths.
        Caprimulgidae, Goatsuckers.
Order Micropodiformes, Swifts, Hummingbirds.
    Suborder Micropodi, Swifts.
        Family Aegialornithidae,[7] *Aegialornis* (fossil).
        Micropodidae, Swifts.
        Hemiprocnidae, Crested Swifts.
    Suborder Trochili, Hummingbirds.
        Family Trochilidae, Hummingbirds.
Order Coliiformes, Colies.
    Family Coliidae, Colies.
Order Trogoniformes, Trogons.
    Family Trogonidae, Trogons.
Order Coraciiformes, Kingfishers, Bee-eaters, Rollers, Hornbills.
    Suborder Alcedines, Kingfishers, Todies, Motmots.
    Superfamily Alcedinoidea, Kingfishers.
        Family Alcedinidae, Kingfishers.
    Superfamily Todoidea, Todies.
        Family Todidae, Todies.

---

[7] Placed here provisionally. See Lambrecht, Handbuch der Palaeornithologie, 1933, pp. 623-624.

Superfamily Momotoidea, Motmots.
    Family Momotidae, Motmots.
Suborder Meropes, Bee-eaters.
    Family Meropidae, Bee-eaters.
Suborder Coracii, Rollers, Hoopoes.
        Family Coraciidae, Rollers.
                Leptosomatidae, Cuckoo-rollers and Ground-
                    rollers.
                Upupidae, Hoopoes.
                Phoeniculidae, Wood-hoopoes.
Suborder Bucerotes, Hornbills.
    Family Bucerotidae, Hornbills.
Order Piciformes, Jacamars, Barbets, Toucans, Woodpeckers.
    Suborder Galbulae, Jacamars, Barbets, Toucans.
        Superfamily Galbuloidea, Jacamars, Puff-birds.
            Family Galbulidae, Jacamars.
                    Bucconidae, Puff-birds.
        Superfamily Capitonoidea, Barbets, Honey-guides.
            Family Capitonidae, Barbets.
                    Indicatoridae, Honey-guides.
        Superfamily Ramphastoidea, Toucans.
        Family Ramphastidae, Toucans.
    Suborder Pici, Woodpeckers.
        Family Picidae, Woodpeckers, Piculets.
Order Passeriformes, Perching Birds.
    Suborder Eurylaimi, Broadbills.
        Family Eurylaimidae, Broadbills.
    Suborder Tyranni, Ovenbirds, Tyrant Flycatchers, and
                Allies.
        Superfamily Furnarioidea, Ovenbirds, Wood-hewers, and
                    Allies.
            Family Dendrocolaptidae, Wood-hewers.
                    Furnariidae, Ovenbirds.
                    Formicariidae, Ant-thrushes.
                    Conopophagidae, Ant-pipits.
                    Rhinocryptidae, Tapaculos.
        Superfamily Tyrannoidea, Tyrant Flycatchers, Pittas,
                    and Allies.
            Family Cotingidae, Cotingas.
                    Pipridae, Manakins.
                    Tyrannidae, Tyrant Flycatchers.
                    Oxyruncidae, Sharp-bills.

     Phytotomidae, Plant-cutters.
     Pittidae, Pittas.
     Acanthisittidae, New Zealand Wrens.
     Philepittidae, Asities.
  Suborder Menurae, Lyre-birds.
    Family Menuridae, Lyre-birds.
     Atrichornithidae,[8] Scrub-birds.
  Suborder Passeres, Song Birds.
    Family Alaudidae, Larks.
     Palaeospizidae, *Palaeospiza* (fossil).
     Hirundinidae, Swallows.
     Campephagidae, Cuckoo-shrikes.
     Dicruridae, Drongos.
     Oriolidae, Old World Orioles.
     Corvidae, Crows, Magpies, Jays.
     Paradiseidae,[9] Birds of Paradise.
     Paradoxornithidae, Parrot-bills, Suthoras.
     Paridae, Titmice.
     Sittidae, Nuthatches.
     Hyposittidae, Coral-billed Nuthatches.
     Certhiidae, Creepers.
     Chamaeidae, Wren-tits.
     Timaliidae, Babbling Thrushes.[10]
     Pycnonotidae, Bulbuls.
     Cinclidae, Dippers.
     Troglodytidae, Wrens.
     Mimidae, Thrashers, Mockingbirds.
     Turdidae,[11] Thrushes.
     Zeledoniidae, Wren-thrushes.
     Sylviidae, Old World Warblers.
     Regulidae, Kinglets.
     Muscicapidae, Old World Flycatchers.
     Prunellidae, Accentors, Hedge-sparrows.
     Motacillidae, Wagtails, Pipits.
     Bombycillidae, Waxwings.
     Ptilogonatidae, Silky Flycatchers.
     Dulidae, Palm-chats.

---

[8] Position not fully established.

[9] Includes the bower-birds, sometimes recognized as the family Ptilinorhynchidae.

[10] Frequently written Timeliidae but formed from the generic name *Timalia*.

[11] Includes the group of fork-tails placed by some in the family Enicuridae.

Artamidae, Wood-swallows.
Vangidae, Vanga Shrikes.
Laniidae, Shrikes.
Prionopidae, Wood-shrikes.
Cyclarhidae, Pepper-shrikes.
Vireolaniidae, Shrike-vireos.
Sturnidae,[12] Starlings.
Melithreptidae, Honey-eaters.
Nectariniidae, Sun-birds.
Dicaeidae, Flower-peckers.
Zosteropidae, White-eyes.
Vireonidae, Vireos.
Coerebidae, Honey-creepers.
Drepanididae, Hawaiian Honey-creepers.
Compsothlypidae, Wood Warblers.
Ploceidae, Weaver-finches.
Icteridae, Blackbirds, Troupials.
Tersinidae, Swallow-tanagers.
Thraupidae, Tanagers.
Catamblyrhynchidae, Plush-capped Finches.
Fringillidae, Grosbeaks, Finches, Buntings.

[12] Includes the glossy starlings or Graculidae of various authors.

CHECK-LIST OF THE TERRESTRIAL AND FRESH-WATER ISOPODA OF OCEANIA

BY

HAROLD GORDON JACKSON

Department of Zoology, Birkbeck College,
University of London

CHECK-LIST OF THE TERRESTRIAL AND FRESH-WATER ISOPODA OF OCEANIA

BY

HAROLD GORDON JACKSON

Department of Zoology, Birkbeck College,
University of London

CHECK-LIST OF THE TERRESTRIAL AND FRESH-WATER ISOPODA OF OCEANIA *

By HAROLD GORDON JACKSON

*Department of Zoology, Birkbeck College,
University of London*

INTRODUCTION

The geographical classification of the Pacific island groups used in this check-list is that employed by the Bernice P. Bishop Museum, and is as follows:

Polynesia: Austral, Chatham, Cook, Easter, Ellice, Hawaii (Hawaii to Kure), Kermadec, Line (Palmyra to Jarvis), Manihiki, Marquesas, New Zealand, Phoenix, Samoa, Society, Tokelau (Union), Tonga, Tuamotu.

Melanesia: Admiralty, Bismarck Archipelago, Fiji, Loyalty, New Caledonia, New Hebrides, Santa Cruz, Solomon, Trobriand.

Micronesia: Bonin, Caroline, Gilbert, Marianas (Guam), Marshall, Palau, Volcano, Wake.

Records from Juan Fernandez and the Galápagos Islands have not been included. (For these see Van Name, 1936, pp. 40 and 41.)

References are, as a rule, restricted to Oceania, but a reference or synonym which seemed in danger of being overlooked is included even though it ranged wider.

The types of the genera dealt with below have been nominated in relatively few cases and, in case of doubt, I have chosen the earliest described species which has been most frequently recorded, or which has page preference in the original description. The type locality is given in each case as nearly as the original description allows.

Such a list as this must, perforce, contain a number of species of doubtful validity, as many of the earlier descriptions, especially of the Armadilline genera, do not suffice to identify the original species. Anyone who works on Pacific species must acknowledge his debt to Verhoeff, but I cannot follow him in all his subdivisions of *Philoscia*

and *Ligia* and have reduced many of his genera to subgenera in these groups. I agree with Van Name (1936) that the division of *Philoscia* into a number of full genera "involves losing sight of important resemblances and relationships in the effort to emphasize small differences," and I consider that the same applies to *Ligia*. There is no doubt, however, that large numbers of forms which still fall under the genera *Spherillo* and *Cubaris* must be further subdivided or reduced by synonymy.

The history of the nomenclature of these forms must be briefly considered in order to explain the divisions adopted in the following pages. Those which were known at the time were placed by Brandt (1833) in three genera: *Armadillo (A. officinalis), Cubaris (C. murina, cinerea,* and *brunnea),* and *Diploexochus (D. echinatus).* Budde-Lund (1885 and 1904) grouped all under *Armadillo* and in 1904 resurrected *Spherillo* Dana for a great army of new but related forms. However, many authors, rejecting both these names, made use of *Cubaris* for the whole group.

It is obvious that such a large assemblage of forms showing considerable diversity of character under their common likeness of structure cannot continue to be known under one or two all-embracing generic names, and the first step in subdividing them must be to go back to Brandt's three clearly defined genera. Here we are fortunately on firm ground (provided that the name *Armadillo* is retained [1]), as the types are well known and undoubtedly are "good" species, but if confusion is to be avoided it is essential that the genera be closely and strictly founded on the named types (for example, Budde-Lund defined *Diploexochus* very much wider than the type and has been followed by other authors).

Probably only one of Brandt's genera *(Cubaris)* is a genuine Pacific genus, but there is a great assemblage of related forms which Budde-Lund lumped under the one genus *Spherillo.*

This complex of forms has yet to be completely sorted, but Verhoeff (1926) is responsible for the first serious attempt to impose order and it seems probable his genera will stand. Unfortunately he has not defined them in relation to the tentative sections (Budde-Lund, XII, Wahrberg, XVI) which were already set up. It is clear that his genus *Sphaerillo* (which is a homonym of *Spherillo* Dana according to Article 35) contains the species placed by Budde-Lund under section XIII of *Spherillo* (Wahrberg's section XVI), and it would only intensify confusion to disagree with this now. If we seek

---

[1] See Jackson, 1933b, p. 148 for further discussion.

for a type for this section it appears that we must nominate *Spherillo danae* Heller 1868, which Heller wrongly attributed to Dana's genus. Of the remaining sections of *Spherillo*, VIII is now divided between *Australiodillo* Verhoeff and *Hawaiodillo* Verhoeff, X is *Merulana* Budde-Lund, and XI (Wahrberg XIII) is *Merulanella* Verhoeff. The remaining sections await analysis, although most of them are probably entitled to generic rank.

Verhoeff's remaining genera would appear to fall outside the already described species of Budde-Lund's composite genus *Spherillo*, but his *Nesodillo* (by Verhoeff's admission, 1938) contained *Cubaris murina* Brandt (*Armadillo murinus* Budde-Lund) and the genera are therefore synonyms. The genus *Cubaris* is thus clearly defined by Brandt and Verhoeff and must be used only in this restricted sense. The rejection of *Nesodillo* is fortunate in another way, as it avoids any confusion with the same author's *Mesodillo*.

Past and present workers on the assemblage of terrestrial isopods under consideration have so consistently neglected to apply the International Rules of Nomenclature that it is too late to do more than protest formally and, in the interest of clarity, accept the status quo. On these grounds it is suggested that *Sphaerillo* Verhoeff be retained as the generic name of the forms included under Budde-Lund's section XIII (Wahrberg XVI) and that *Spherillo* should be allowed to die out, as its species are absorbed into new or already existing genera.

The origin of the land isopod fauna of Oceania is a problem upon which speculation may easily outrun the available data, but the following facts are of interest. About 155 species have been recorded from Pacific Islands and of these 139 are peculiar to this area. Of the 16 recorded from elsewhere 6 are cosmopolitan, 6 are also recorded from Malaysia and the Indian Ocean and 4 from South America. Of the latter, 1 (*Trichoniscus magellanicus*) is Antarctic, 2 are semimarine (*Ligia novaezealandiae* and *Deto bucculenta*) and present no problem of transport, and the remaining 1 (*Rhyscotus ortonedae*) is known by a single specimen recorded from Samoa and is an obvious introduction. From the fact that records of the *Ligia* and *Deto* are numerous from New Zealand and its islands and solitary from Chile it is reasonably probable that the former locality is the home of both. If they had been natives of Chile they might be expected to be more widely spread along the American coast.

The credentials of the western fauna are more respectable. *Philoscia angusticauda* is recorded from Borneo and Hawaii; *Cubaris murina*, although first recorded from Brazil, is widely distributed in Malaysia

and the Indian Ocean; *Spherillo testudinalis* is from the Bay of Bengal; *Philoscia truncata* is from Malaysia; and *Trichoniscus verrucosus* is from the Crozets (South Indian Ocean). Surprisingly few are shared with Australia, but it is not surprising that the Polynesian area shows no relationship with Hawaii, which is relatively poor in terrestrial isopods.[2]

Of this large residue of species more than half belong to the Armadillinae and about 50 of these to the conglobating forms included by Budde-Lund under the name "Spherillo." These forms may be considered to be the characteristic woodlice of the whole area, and it is significant that such a large assemblage of forms with short bushy penicilli on the maxillula are grouped together in the Pacific basin, even if the fact does not justify Budde-Lund's creation of a subfamily to contain them.

The only other group of species which approaches the Armadillinae in numbers is that comprised under the general name "Philoscia," of which there are 28 recorded.

In spite of the richness of species in Oceania, there are few records of endemic genera. Each group shows considerable uniformity, and specific and even generic differences are founded on minute points of no great moment. It would be reasonable therefore to postulate a recent origin for the majority of the woodlice of Oceania.

The terrestrial isopods, in spite of this wide distribution, would seem to be singularly ill-provided with means of dispersal. They are dependent on the maintenance of a high humidity, they have small powers of locomotion and must await the accidental carriage of a gravid female for colonizing distant places. Even the smallest are too large and unprotected to be carried easily by birds, like seeds or small eggs, except for very short distances, but transportation by hurricanes, perhaps with portions of plants, is by no means out of the question. The powers of distribution possessed by wind storms are shown, in this area, in records which "are marvellous to the point almost of embarrassment" (Gulick).[3] Usually terrestrial isopods must rely on driftwood or the cooperation of man in spreading over the remoter parts of the earth.

Between the groups of islands driftwood is probably the most usual means of dispersal, which can take place in any direction in spite of the prevailing trade wind. The British Admiralty sailing instructions takes particular notice of "singular interruptions to the trade

---

[2] Verhoeff, however, records *Ligia hawaiensis* from Fiji (1938).
[3] Gulick, A., Quart. Rev. Biol., vol. 7, p. 415, 1932.

wind, unknown currents and strong squalls" among these islands, which might assist the random distribution of drift and these conditions have presumably persisted *mutatis mutandis* for the greater part of the Tertiary period, prior to which we have neither knowledge of the existence of terrestrial isopods nor reliable information on the conformation of land in the Pacific. There is certainly no confirmation of the existence of the NW. to SE. land chains, which are admittedly geologically possible, in the present distribution of the Pacific woodlice, or any indication that they traveled there by land.

It is significant in this connection that a large proportion of woodlice from the Pacific Islands belong to the Armadillinae—that is to say to a group which is strikingly adapted to resist desiccation but with very poor powers of locomotion. They may well have survived transportation by natural means from early times, and it may be assumed that the great variety of species of *Philoscia,* which, with their lightly calcified integument, exposed ventral surface, and low birth rate are ill-formed for rigorous conditions, have appeared with the free introduction of plants characteristic of man's activities, which gives the woodlouse a means of conveyance under conditions of the requisite high humidity.

It is believed to be highly probable that Polynesia was peopled by races which came from the west via India and Malaysia, and they may have been responsible for the woodlice with western affinities. Later dispersals in both directions were possibly made by the seventeenth- and eighteenth-century explorers of the Pacific and later still by the copra trade, which followed the same general route as the earliest settlers.

Speculation on the distribution of the Oniscoidea is inevitably checked by our ignorance of the rate at which modification may have taken place and, though the ancestral form of the "Spherillo" group may have had its origin in the land masses on the western border of the Pacific basin bounded by the line New Zealand—Tonga—Fiji—New Hebrides—Solomon and have spread east and west from island to island by natural means of dispersal, it is also within the bounds of possibility that they have not preceded man. Nevertheless, it must not be forgotten that two of the most modified forms, *Tridentodillo* and *Echinodillo,* come from the most isolated group of islands, the Marquesas, at considerable altitudes. I have suggested elsewhere (1933b) that these may be gerontic forms preserved from extinction by their inaccessible habitat.

The "Philoscias" more probably appeared with the earliest settlers in much more recent times, although *Cerberoides* from Rapa (Aus-

trals), whose affinities are with the Oniscinae, can scarcely be accounted for in that way. Its three subgenera provide a beautiful example of adaptive radiation, which, one feels, must have had more leisure to work itself out than the advent of man could have provided.

Finally, there is a group of sub-Antarctic forms—*Actaecia, Scyphoniscus, Scyphax,* and *Deto*—distinctly lower in the evolutionary scale, which have made their appearance in the extreme south and which contribute nothing to the wider problem.

To sum up: The woodlice of Oceania for the most part consist of forms belonging to the Armadillid or Oniscid type of structure. The Porcellionidae and the more terrestrial families of the Atracheata are almost unrepresented except by obvious recent introductions. These statements are almost equally applicable to the great land masses bordering the Pacific, but the fauna of Oceania is less rich than they in characteristic genera. Endemic species are certainly numerous, but the range of differences does not encourage the belief that they have been separated from one another for great periods of time, but rather that variations have occurred freely, after random population of the islands, under conditions which encourage their appearance and survival.

The assumption of land connections between the islands is gratuitous and would seem to provide more time than is necessary to account for the comparatively small range of differences observed, while the assumption that man is responsible would seem to provide too little.

There remains random distribution by hurricanes and other accidental means, which is probably adequate to explain the present distribution and to account for the greater individuality of more remote islands such as the Marquesas and the Australs.

Suborder ONISCOIDEA
Superfamily ATRACHEATA
Family LIGIIDAE
Genus LIGIA Fabricius, 1792

(Type, *Oniscus oceanicus* Linné)

Ligia (Megaligia) exotica Roux: Roux, 1828, pl. 13; Budde-Lund, 1879, p. 8; 1885, p. 266; Dollfus, 1893, p. 24; Richardson, 1905, p. 676 (*Ligyda*); Jackson, 1922, p. 693; Panning, 1924, p. 196; Verhoeff, 1926, p. 348 (*Megaligia*); Jackson, 1927b, p. 11; Verhoeff, 1928a, p. 116; Van Name, 1936, p. 48 (q.v. for further references).

Synonyms: *L. gaudichaudi* Milne-Edwards, 1840, p. 157.
          L. grandis Perty, 1830-34, p. 212.
          ? *L. malleata* Pfeffer, 1889, p. 36 (Jackson, 1922, p. 701).
Hawaii (Oahu) ; Samoa (Tutuila) ; New Zealand.
(Type locality, Mediterranean.)

Ligia (Megaligia) hawaiensis DANA: Dana, 1853, p. 740; Budde-Lund, 1885,
          p. 271; Jackson, 1922, p. 696; Verhoeff, 1928a, p. 116 (*Megaligia*) ; Jack-
          son, 1933b, p. 149; Van Name, 1936, p. 52; Verhoeff, 1938, p. 12.
Hawaii (Oahu and Kauai) ; Fiji (Viti Levu).
(Type locality, Hawaiian Islands.)

Ligia (Megaligia) perkinsi (DOLLFUS): Dollfus, 1900, p. 525 (*Geoligia*) ; Jack-
          son, 1922, p. 699; Chilton, 1922, p. 83; 1924a, p. 894; Verhoeff, 1926, p. 354;
          Jackson, 1927a, p. 134; 1927b, pp. 3 and 11.
Hawaii (Hawaii, Kauai) ; Samoa (Namua).
(Type locality, Hawaiian Islands.)

Ligia (Nesoligia) novaezealandiae DANA: Dana, 1853, p. 739 (*Lygia novi-
          zealandiae*) ; Miers, 1876b, p. 103; Filhol, 1885, p. 444; Budde-Lund, 1885,
          p. 271; Thomson and Chilton, 1886, p. 157; Chilton, 1901, p. 106; 1910b,
          p. 287; 1911, p. 568; Jackson, 1922, p. 697; Chilton, 1924b, p. 287; Pan-
          ning, 1924, p. 196; Verhoeff, 1926, p. 348 (*Nesoligia*) ; Barnard, 1932,
          p. 185; Van Name, 1936, pp. 54, 57 (? = *L. litigiosa* Wahrberg, 1922b,
          p. 277).
Synonyms: *L. quadrata*, Thomson, 1879a, p. 232; Filhol, 1885, p. 444.
          L. porteri, Maccagno, 1931, p. 151.
          L. cursor Budde-Lund (see Jackson, 1922, p. 697).
Stewart Island ; New Zealand; Sunday Island, Victoria; Chile.
(Type locality, Bay of Islands, New Zealand.)

Ligia (Euryligia) latissima VERHOEFF: Verhoeff, 1926, p. 349.
(Type locality, New Caledonia.)

Ligia rugosa JACKSON: Jackson, 1938, p. 172.
Tuamotus (Mangareva) ; Australs (Marotiri).
(Type locality, Tuamotus [Mangareva].)

Ligia philoscoides JACKSON: Jackson, 1938, p. 173.
(Type locality, Australs [Rapa].)

Ligia pallida JACKSON: Jackson, 1938, p. 175.
(Type locality, Christmas Island.)

Ligia vitiensis DANA: Dana, 1853, p. 741; Budde-Lund, 1885, p. 271; Stebbing,
          1900b, p. 646; Jackson, 1922, p. 696 (*L. hawaiensis*) ; 1933b, p. 149; 1938,
          p. 172.
Fiji ; New Guinea; Marquesas (Eiao) ; Tuamotus (Mangareva).
(Type locality, Fiji.)

Genus **STYLONISCUS** Dana, 1858

(Type, *Styloniscus longistylis* Dana)

Styloniscus longistylis DANA: Dana, 1853, p. 737; Budde-Lund, 1885, p. 271.
(Type locality, Tongatabu [Friendly].)

Family TRICHONISCIDAE

Genus TRICHONISCUS Brandt, 1833

(Type, *Trichoniscus pusillus* Brandt)

Synonym: *Philougria* Bate and Westwood, 1868.

Trichoniscus (Megatrichoniscus) thomsoni CHILTON: Chilton, 1886, p. 159
   (*Philygria*) ; 1901, p. 118; Budde-Lund, 1906, p. 83; Chilton, 1909a, p. 661;
   Wahrberg, 1922a, p. 79; Stephensen, 1927, p. 371; Jackson, 1938, p. 176
   (*Megatrichoniscus*).
   Auckland Islands; New Zealand; Australs (Rapa).
   (Type locality, South Island, New Zealand.)

Trichoniscus (Megatrichoniscus) magellanicus (DANA): Dana, 1853, p. 736
   (*Styloniscus*) ; Budde-Lund, 1885, p. 271 (*Styloniscus*) ; Stebbing, 1900a,
   p. 566 (*Trichoniscus*) ; Chilton, 1901, p. 106 (*Styloniscus*) ; Budde-Lund,
   1906, p. 83; Chilton, 1909a, pp. 602 and 661; 1910b, p. 287; 1915b, p. 453;
   Wahrberg, 1922a, p. 76; Stephensen, 1927, p. 370; Van Name, 1936, p. 82.
   New Zealand.
   (Type locality, Tierro del Fuego, Nassau Bay.)

Trichoniscus phormianus CHILTON: Chilton, 1901, p. 115.
   Synonym: *Philongria rosea* Chilton, 1883a, p. 73; 1883c, p. 149; Thomson
      and Chilton, 1886, p. 157.
   New Zealand.
   (Type locality, Canterbury, New Zealand.)

Trichoniscus otakensis CHILTON: Chilton, 1901, p. 117; 1910b, p. 287; ? Wahr-
      berg, 1922a, p. 76; Chilton, 1925a, p. 319; Stephensen, 1927, p. 370.
   Synonym as for *T. phormianus*.
   South Island, New Zealand; Chatham Island.
   (Type locality, South Island, New Zealand.)

Trichoniscus commensalis CHILTON: Chilton, 1910a, p. 191.
   New Zealand, "North Island and wider" (from ants' nests).
   (Type locality, New Plymouth, New Zealand.)

Trichoniscus verrucosus BUDDE-LUND: Budde-Lund, 1906, p. 79; Chilton, 1909a,
      p. 602; 1910b, p. 287; 1915b, p. 453 (? = *T. magellanicus*) ; Wahrberg,
      1922a, p. 72; Van Name, 1936, p. 83.
   Sub-Antarctic islands of New Zealand and Marion Island.
   (Type locality, Crozets.)

Trichoniscus kermadecensis CHILTON: Chilton, 1911, p. 569.
   Kermadec Islands.
   (Type locality, Sunday Island, Kermadec Islands.)

Genus NOTONISCUS Chilton, 1915

(Type, *Haplophthalmus helmsii* Chilton)

Notoniscus helmsii (CHILTON) : Chilton, 1901, p. 119 (*Haplophthalmus*) ; 1915a,
   p. 418.
   New Zealand.
   (Type locality, Greymouth, New Zealand.)

Notoniscus australis (Chilton): Chilton, 1909a, p. 662 (*Haplophthalmus*);
    1915a, p. 421.
    (Type locality, Campbell Island.)

Superfamily HYPOTRACHEATA

Family TYLIDAE

Genus TYLOS Audouin and Savigny, 1827

(Type, *Tylos latreillei* Audouin and Savigny)

Tylos neozelanicus Chilton: Chilton, 1901, p. 120; Budde-Lund, 1906, p. 78;
    Chilton, 1910b, p. 288.
    New Zealand.
    (Type locality, Wellington, New Zealand.)

Superfamily PLEUROTRACHEATA

Family SCYPHACIDAE (=DETONIDAE)

Genus SCYPHAX Dana, 1853

(Type, *Scyphax ornatus* Dana)

Scyphax ornatus Dana: Dana, 1853, p. 734; Miers, 1876b, p. 101; Budde-Lund,
    1879, p. 2; 1885, p. 233; Filhol, 1885, p. 443; Thomson and Chilton, 1886,
    p. 158; Chilton, 1901, p. 123.
    Synonyms: *Scyphax intermedius* Miers: Miers, 1876a, p. 227; 1876b, p. 102;
        Thomson and Chilton, 1886, p. 158.
        Philoscia violacea Filhol, 1885, p. 445.
    "On sandy shores in the North Island and also from Westport. Not found
    in the south of South Island." (Chilton, 1901.)
    (Type locality, New Zealand.)

Scyphax setiger Budde-Lund: Budde-Lund, 1885, p. 232.
    (Type locality, New Caledonia.)

Genus DETO Guérin, 1836

(Type, *Deto echinata* Guérin)

Deto (Vinetta) aucklandiae (G. M. Thomson): Thomson, 1879b, p. 249 (*Ac-
    taecia*); Budde-Lund, 1885, p. 239 (*Actaecia*); Filhol, 1885, p. 443
    (*Actaecia*); Chilton, 1901, p. 126 (*Scyphax* ?); 1906b, p. 273; Budde-
    Lund, 1906, p. 87; Chilton, 1909a, p. 666; 1910b, p. 288; 1915b, p. 445;
    Stephensen, 1927, p. 371.
    Synonyms: *Deto magnifica* Budde-Lund, 1906, p. 86.
        Deto robusta Budde-Lund, 1906, p. 87.
    (Type locality, Ewing Island in Auckland Islands group.)

Deto (Vinetta) bucculenta (NICOLET) : Nicolet, 1849, p. 267 (*Oniscus* ♂) ;
Budde-Lund, 1885, p. 206 (*Oniscus*) ; Chilton, 1915b, p. 449.
   Synonyms: *Oniscus tuberculatus* (♀) Nicolet, 1849, p. 268; Budde-Lund,
      1885, p. 206.
         Oniscus novae-zealandiae Filhol, 1885, p. 441; Budde-Lund, 1906,
            p. 87.
         Scyphax (?) *aucklandiae* Chilton, 1901, p. 126.
         Deto novae-zealandiae Chilton, 1906b, p. 273; Budde-Lund, 1906,
            p. 87; Chilton, 1909a, p. 667; 1910b, p. 288.
   Chatham Island, Stewart Island, Wellington, New Zealand.
   (Type locality, Valparaiso Bay, South America.)

Genus SCYPHONISCUS Chilton, 1901

(Type, *Scyphoniscus waitatensis* Chilton)

Scyphoniscus waitatensis CHILTON : Chilton, 1901, p. 128; 1910b, p. 288.
   (Type locality, Blueskin Bay, Otago, New Zealand.)

Scyphoniscus magnus CHILTON : Chilton, 1909a, p. 665.
   (Type locality, Auckland and Campbell Islands.)

Genus ACTAECIA Dana, 1853

(*Cylloma* Budde-Lund, 1885)

(Type, *Actaecia euchroa* Dana)

Actaecia euchroa DANA : Dana, 1853, p. 735; Miers, 1876b, p. 102; Thomson,
   1879b, p. 249; Filhol, 1885, p. 443; Thomson and Chilton, 1886, p. 158;
   Thomson, 1893, p. 56 (12 in reprint) ; Chilton, 1901, p. 130; 1910b, p. 288.
   Synonym: *Armadilloniscus euchroa* Budde-Lund, 1885, p. 239.
   New Zealand.
   (Type locality, Bay of Islands, New Zealand.)

Actaecia opihensis CHILTON : Chilton, 1901, p. 132; 1910b, p. 288.
   (Type locality, Timaru, New Zealand.)

Family ONISCIDAE

Subfamily ONISCINAE

Genus PHILOSCIA Latreille, 1804

(Type, *Oniscus muscorum* Scopoli)

Philoscia australis SEARLE : Searle, 1914, p. 365.
   (Type locality, Marquesas [Nukuhiva].)

Philoscia lifuensis STEBBING : Stebbing, 1900b, p. 648; Budde-Lund, 1912, p. 386
   (? *Setaphora*) ; Verhoeff, 1926, p. 356, ? = *P.* (*Chaetophiloscia*) *rouxi*
   Verhoeff.
   (Type locality, Lifu, Loyalty Islands.)

Philoscia novae-zealandiae FILHOL: Filhol, 1885, p. 441; Chilton, 1901, p. 138; 1910b, p. 289.
(Type localities, New Zealand and Stewart Island.)

Philoscia oliveri CHILTON: Chilton, 1911, p. 570.
(Type locality, Sunday Island, Kermadec Islands.)

Philoscia persona JACKSON: Jackson, 1938, p. 178.
(Type locality, Australs [South East Islet, Marotiri].)

Philoscia pubescens (DANA): Dana, 1853, p. 730 (*Oniscus*); Miers, 1876b, p. 99 (*Oniscus*); Filhol, 1885, p. 440 (*Oniscus*); Budde-Lund, 1885, p. 223; Thomson and Chilton, 1886, p. 158 (*Oniscus*); Chilton, 1901, p. 136; Budde-Lund, 1904, p. 43; 1906, p. 71; Chilton, 1910b, p. 289; Barnard, 1932, p. 244.
Auckland.
(Type locality, Whykare River, Auckland, New Zealand.)

Philoscia societatus MACCAGNO: Maccagno, 1932, p. 4.
(Type locality, Society Islands [Moorea].)

Philoscia squamosa JACKSON: Jackson, 1938, p. 180; var. *setosa* Jackson, 1938, p. 181.
(Type locality, Australs [South East Islet, Marotiri].)

Philoscia (Chaetophiloscia) rouxi VERHOEFF: Verhoeff, 1926, p. 345 (*Laevophiloscia*); Verhoeff, 1928b, p. 218 (*Laevophiloscia = Chaetophiloscia*) ? = *P. lifuensis* Stebbing q. v.
Loyalty Islands.
(Type locality, Maré, Loyalty Islands.)

Philoscia (Heroldia) appressa VERHOEFF: Verhoeff, 1926, p. 342.
New Caledonia.
(Type locality, Tchalabel, New Caledonia.)

Philoscia (Heroldia) canalensis VERHOEFF: Verhoeff, 1926, p. 342.
New Caledonia.
(Type locality, Panié Mountain, New Caledonia.)

Philoscia (Heroldia) digitifera VERHOEFF: Verhoeff, 1926, p. 338; 1926, p. 339 (var. *marmorata*).
New Caledonia.
(Type locality, Humboldt Mountain, New Caledonia.)

Philoscia (Heroldia) humboldtii VERHOEFF: Verhoeff, 1926, p. 340.
New Caledonia.
(Type locality, Humboldt Mountain, New Caledonia.)

Philoscia (Heroldia) monticola VERHOEFF: Verhoeff, 1926, p. 344; 1926, p. 345 (subsp. *paniensis*).
New Caledonia.
(Type locality, Ignambi Mountain, New Caledonia.)

Philoscia (Heroldia) reticulata VERHOEFF: Verhoeff, 1926, p. 339.
New Caledonia.
(Type locality, Ignambi Mountain, New Caledonia.)

Philoscia (Nesoniscus) longicornis VERHOEFF: Verhoeff, 1926, p. 329.
New Caledonia.
(Type locality, Ignambi Mountain, New Caledonia.)

Philoscia (Nesoniscus) noduligerus VERHOEFF: Verhoeff, 1926, p. 330; 1926,
p. 331 (subsp. *minor*).
New Caledonia.
(Type locality, Ignambi and Panié Mountains, New Caledonia.)

Philoscia (Oroscia) paniensis VERHOEFF: Verhoeff, 1926, p. 328.
New Caledonia.
(Type locality, Panié, New Caledonia.)

Philoscia (Oroscia) squamuligera VERHOEFF: Verhoeff, 1926, p. 325.
New Caledonia.
(Type locality, Ngoi Tal and Humboldt Mountain, New Caledonia.)

Philoscia (Paraphiloscia) brevicornis BUDDE-LUND: Budde-Lund, 1912, p. 374
(*Pseudophiloscia*).
(Type locality, Auckland, New Zealand.)

Philoscia (Paraphiloscia) fragilis (BUDDE-LUND): Budde-Lund, 1904, p. 43
(*Pseudophiloscia*).
Synonym: *Philoscia pubescens* Chilton, 1901, p. 136, *ex parte*.
Auckland and Howick, New Zealand.
(Type locality, Howick, New Zealand.)

Philoscia (Paraphiloscia) gracilis BUDDE-LUND: Budde-Lund, 1879, p. 2; 1885,
p. 220; Stebbing, 1900b, p. 647; Budde-Lund, 1904, p. 42 (*Pseudophilos-
cia*); 1912, p. 372 (*Pseudophiloscia*); *ibid.* note by Stebbing, p. 372 (*Para-
philoscia*); Jackson, 1927b, p. 8; 1938, p. 178 (var. *australis*).
Lifu, Loyalty Islands ?; Samoan Islands; Australs (Tubuai).
(Type locality, Upolu, Samoan Islands.)

Philoscia (Paraphiloscia) stenosoma STEBBING: Stebbing, 1900b, p. 648.
(Type locality, New Britain.)

Philoscia (Plymophiloscia) montana VERHOEFF: Verhoeff, 1926, p. 334.
New Caledonia.
(Type locality, Canala and Humboldt Mountains, New Caledonia.)

Philoscia (Setaphora) angusticauda BUDDE-LUND: Budde-Lund, 1885, p. 216;
Dollfus, 1900, p. 525; Budde-Lund, 1912, p. 386 (*Setaphora*); Arcangeli,
1927, p. 259; Jackson, 1936, p. 81.
Hawaii (Honolulu, Oahu).
(Type locality, Borneo.)

Philoscia (Setaphora ?) fasciata JACKSON: Jackson, 1933a, p. 87; 1933b, p. 151;
1938, p. 181.
Marquesas (Tahuata, Nukuhiva, Hivaoa, Fatuhiva, Uahuka); Tuamotus
(Mangareva, Henderson); Pitcairn; Australs (Tubuai, Rapa, Rurutu,
Raivavae); Society Islands (Tahiti, Moorea).
(Type locality, Marquesas.)

Philoscia (Setaphora) truncata DOLLFUS: Dollfus, 1898, p. 376; Stebbing, 1900b, p. 647; Budde-Lund, 1912, p. 386 (? *Setaphora*); Arcangeli, 1927, p. 260; Herold, 1931, p. 383; Jackson, 1933b, p. 150; 1938, p. 177.

New Britain; Marquesas (Fatuhiva, Nukuhiva, Uapou); Tuamotus (Mangareva); Australs (Tubuai, Rapa); Society Islands (Tahiti, Moorea, Huahine, Raiatea).

(Type locality, Celebes and Flores.)

Philoscia (Wahrbergia) sarasini VERHOEFF: Verhoeff, 1926, p. 333.

New Caledonia.

(Type locality, Ignambi and Canala Mountains, New Caledonia.)

Genus ONISCUS Linnaeus, 1758

(Type, *Oniscus asellus* Linné)

Oniscus cookii FILHOL: Filhol, 1885, p. 442; Chilton, 1901, p. 136 (? = "*Oniscus kenepurensis*"); 1910b, p. 288. "Sous les pierres sur la portion ouest de l'île du milieu de la Nouvelle-Zélande" (Filhol).[4]

Genus PHALLONISCUS Budde-Lund, 1908

(Type, *Oniscus punctatus* Thomson)

Phalloniscus punctatus (THOMSON): Thomson, 1879a, p. 232 (*Oniscus*); Budde-Lund, 1885, p. 206 (*Oniscus*); Filhol, 1885, p. 440 (*Oniscus*); Thomson and Chilton, 1886, p. 158 (*Oniscus*); Chilton, 1901, p. 133 (*Oniscus*); 1906b, p. 273 (*Oniscus*); 1909a, p. 668 (*Oniscus*); 1910b, p. 288 (*Oniscus*); Wahrberg, 1922a, p. 91 (*Phalloniscus*); Chilton, 1925a, p. 319; Verhoeff, 1926, p. 331; Stephensen, 1927, p. 372.

New Zealand; Chatham Island; Auckland Islands.

(Type locality, New Zealand.)

Phalloniscus kenepurensis (CHILTON): Chilton, 1901, p. 135 (*Oniscus*); 1910b, p. 288 (*Oniscus*); Wahrberg, 1922a, p. 86 (*Phalloniscus*); Verhoeff, 1926, p. 331.

(Type locality, Kenepuru, New Zealand.)

Genus ALLONISCUS Dana, 1854

(Type, *Alloniscus perconvexus* Dana)

Alloniscus oahuensis BUDDE-LUND: Budde-Lund, 1879, p. 1; 1885, p. 225; Jackson, 1933b, p. 153; 1938, p. 181.

Synonym: *Alloniscus brevis* Budde-Lund, 1885, p. 226; Jackson, 1927b, p. 6 (see Jackson, 1933b, p. 154).

Samoa (Tutuila, Upolu); Marquesas (Hivaoa, Mohotani, Uahuka); Hawaii (Oahu); Tuamotus (Mangareva); Australs (Tubuai, Raivavae); Society Islands (Tahiti); Fanning Island.

(Type locality, Oahu, Hawaiian Islands.)

---

[4] This is almost certainly not an "*Oniscus*." Chilton's suggestion is probable, and in any case it is likely to be a "Phalloniscus."

Alloniscus floresianus DOLLFUS: Dollfus, 1898, p. 374; 1900, p. 524.
  Hawaii (Lanai).
  (Type locality, Flores.)

Genus CERBEROIDES Jackson, 1938

(Type, *Cerberoides pilosus* Jackson)

Cerberoides (Philoscodillo) pilosus JACKSON: Jackson, 1938, p. 183.
  (Type locality, Australs [Rapa Island].)

Cerberoides (Oniscomorphus) bicornis JACKSON: Jackson, 1938, p. 184.
  (Type locality, Australs [Rapa Island].)

Cerberoides (Congloboniscus) brevicauda JACKSON: Jackson, 1938, p. 187.
  (Type locality, Australs [Rapa Island].)

Subfamily PORCELLIONIINAE

Genus PORCELLIO Latreille, 1804

(Type, *Porcellio scaber* Latreille)

Porcellio (Euporcellio) scaber LATREILLE: Latreille, 1804, p. 45; Dollfus, 1900,
  p. 524; Chilton, 1901, p. 139; 1905, p. 429; Jackson, 1938, p. 189.
  Synonym: *Porcellio graniger* Miers, 1876a, p. 226; 1876b, p. 99; Filhol, 1885,
       p. 443; Thomson and Chilton, 1886, p. 158; Thomson, 1892,
       p. 48. For further references and synonymy see Van Name,
       1936, p. 226.
  New Zealand; Hawaii (Kona); Australs (Rapa).
  (Type locality, Europe.)

Porcellio (Mesoporcellio) laevis LATREILLE: Latreille, 1804, p. 46; Dollfus,
  1890b, p. 4; 1900, p. 524; Chilton, 1905, p. 430; Wahrberg, 1922a, p. 182;
  Verhoeff, 1926, p. 321; Jackson, 1933b, p. 155; 1938, p. 187. For further
  references and synonymy see Van Name, 1936, p. 229.
  Hawaii (Lanai, Oahu); New Caledonia; Marquesas (Taiohae); Tuamotus
  (Mangareva).
  (Type locality, Europe.)

Genus PORCELLIONIDES Miers, 1877 (= METOPONORTHUS Budde-Lund, 1885)

(Type, *Porcellio pruinosus* Brandt, 1833)

Porcellionides pruinosus (BRANDT): Brandt, 1833, p. 181 (*Porcellio*); Chilton,
  1901, p. 141; 1905, p. 431; 1906a, p. 64; 1911, p. 571; Searle, 1914, p. 366;
  Wahrberg, 1922a, p. 148; Verhoeff, 1926, p. 321 (except Searle, all the
  above *Metoponorthus*); Jackson, 1933b, p. 155; 1938, p. 190; Verhoeff,
  1938, p. 12 (*Metoponorthus*).
  Synonyms: *Porcellio zealandicus* White, 1847, p. 99; Miers, 1876a, p. 226;
       1876b, p. 100.
       Porcellio neo-zealanicus Thomson and Chilton, 1886, p. 158; Chil-
       ton, 1901, p. 141.

For further references and synonymy see Van Name, 1936, p. 238.
New Zealand; Norfolk Island; Kermadec Islands (Sunday Island); Society
   Islands (Tahiti); Marquesas (Hivaoa, Mohotani Eiao, Fatuuku, Nuku-
   hiva); Tuamotus· (Fakarava); Fanning Island; Fiji (Viti Levu).
(Type locality, Europe.)

Genus NAGARA Budde-Lund, 1908

(Type, *Porcellio cristatus* Dollfus, 1889)

Nagara (Nagara) insularum VERHOEFF: Verhoeff, 1926, p. 315.
(Type locality, Loyalty Islands.)

Nagara (Heminagara) tahitiensis JACKSON: Jackson, 1933a, p. 87; 1938, p. 189.
   Society Islands (Tahiti, Raiatea); Tuamotus (Mangareva); Australs (Tu-
   buai, Maria); Christmas Island?
(Type locality, Society Islands [Tahiti].)

Genus TRICHORHINA Budde-Lund, 1908

(Type, *Bathytropa thermophila* Dollfus)

Trichorhina squamata VERHOEFF: Verhoeff, 1926, p. 319.
(Type locality, Loyalty Islands.)

Subfamily RHYSCOTINAE

Genus RHYSCOTUS Budde-Lund, 1885

(Type, *Rhyscotus turgifrons* Budde-Lund)

Rhyscotus ortonedae BUDDE-LUND: Budde-Lund, 1908, p. 299; Jackson, 1927b,
   p. 6; Van Name, 1936, p. 266.
Samoa (Upolu).
(Type locality, Ecuador.)

Subfamily ARMADILLINAE

Genus ACANTHODILLO Verhoeff, 1926

(Type, *Acanthodillo erinaceus* Verhoeff)

Acanthodillo erinaceus VERHOEFF: Verhoeff, 1926, p. 267.
(Type locality, New Caledonia.)

Genus ARMADILLO Brandt, 1833 amend. Verhoeff, 1926

(Type, *Armadillo officinalis* Duméril)

Armadillo purpurescens (BUDDE-LUND): Budde-Lund, 1912, p. 371 (*Spherillo*);
   Arcangeli, 1933, p. 32.
Synonyms: *Cubaris officinalis* Stebbing (not Duméril); Stebbing, 1900b,
   p. 655.
   ? *Armadillo rouxi* Verhoeff, 1926, p. 311.
New Caledonia.
(Type locality, Isle of Pines, New Caledonia.)

Armadillo (Pseudosphaerillo) insularis ARCANGELI: Arcangeli, 1933, p. 25.
  (Type locality, Samoa [Tutuila].)

Armadillo (Pseudosphaerillo) rouxi VERHOEFF: Verhoeff, 1926, pp. 311 and 357.
  Synonym: *Cubaris officinalis* Stebbing (not Duméril) ; Stebbing, 1900b, p. 655.
  (Type locality, New Caledonia.)

Genus CUBARIS Brandt, 1833 [5] (= NESODILLO Verhoeff, 1926)

(Type, *Cubaris cinerea* or *murina* Brandt)

Cubaris bocki (VERHOEFF): Verhoeff, 1938, p. 9 (*Nesodillo*).
  (Type locality, Gilbert Islands [Aranuka].)

Cubaris canalensis (VERHOEFF): Verhoeff, 1926, p. 282 (*Nesodillo*).
  (Type locality, New Caledonia.)

Cubaris galbineus (ESCHSCHOLTZ): Eschscholtz, 1823, p. 112 (*Armadillo*) ;
    Budde-Lund, 1885, p. 39 (*Armadillo*) ; 1904, p. 120 (? *Spherillo*).
  (Type locality, "Guahm" Island.)

Cubaris incisus (VERHOEFF): Verhoeff, 1926, p. 284 (*Nesodillo*).
  (Type locality, New Caledonia.)

Cubaris javanensis (DOLLFUS): Dollfus, 1889, p. 91 (*Armadillo*) ; 1890b, p. 3
    (*Armadillo*) ; Budde-Lund, 1904, p. 120 (*Armadillo*).
  Hawaii (Oahu).
  (Type locality, Java.)

Cubaris lacustris (VERHOEFF): Verhoeff, 1926, p. 286 (*Nesodillo*).
  (Type locality, New Caledonia.)

Cubaris lifuensis STEBBING: Stebbing, 1900b, p. 653.
  (Type locality, Lifu, Loyalty Islands.)

Cubaris longicornis (VERHOEFF): Verhoeff, 1926, p. 283 (*Nesodillo*).
  (Type locality, New Caledonia.)

Cubaris lundi STEBBING: Stebbing, 1900b, p. 655. (Perhaps a *Sphaerillo*.)
  (Type locality, New Britain.)

Cubaris milleri CHILTON: Chilton, 1917, p. 327. (Probably a new genus related
    to *Sphaerillo*.)
  (Type locality, Wellington, New Zealand.)

Cubaris murina BRANDT: Brandt, 1833, p. 190; Budde-Lund, 1885, p. 27 (*Arma-
    dillo*) ; 1904, p. 119 (*Armadillo*) ; Jackson, 1933a, p. 90; 1933b, p. 157;
    1938, p. 192; Verhoeff, 1938, p. 8.
  Synonym: *Nesodillo medius* Verhoeff, 1926,[6] p. 287.

---

  [5] All species of *Cubaris* Brandt listed below belong to the genus as restricted
by Verhoeff (= *Nesodillo* Verhoeff) except *C. lundi* Stebbing, *C. milleri* Chil-
ton, and *C. suteri* Chilton, which are related to *Sphaerillo* and will ultimately
find a home elsewhere.
  [6] Verhoeff (1938) considers that *C. murina* and *C. medius* are different, but
nearly related, species. An examination of numerous specimens of the former in

For further references and synonymy see Van Name, 1936, p. 387.

Hawaii (Oahu) ; Marquesas (Nukuhiva, Hivaoa, Fatuhiva, Uahuka, Uapou, Mohotani, Eiao) ; Tuamotus (Mangareva) ; Australs (Rapa, Raivavae) ; Society Islands (Tahiti, Moorea) ; Fanning ; New Caledonia.

(Type locality, Brazil.)

Cubaris pacificus (VERHOEFF) : Verhoeff, 1926, p. 284 (*Nesodillo*).
(Type locality, New Caledonia.)

Cubaris plasticus (VERHOEFF) : Verhoeff, 1926, p. 290 (*Nesodillo*).
(Type locality, New Caledonia.)

Cubaris pronyensis (VERHOEFF) : Verhoeff, 1926, p. 289 (*Nesodillo*). *C. pronyensis* var. *erythrocephalus* Verhoeff, 1926, p. 289 (*Nesodillo*).
(Type locality, New Caledonia.)

Cubaris sarasini (VERHOEFF) : Verhoeff, 1926, p. 280 (*Nesodillo*). *C. sarasini* var. *marmoratus* Verhoeff, 1926, p. 280 (*Nesodillo*).
Synonym : *? Cubaris lifuensis* Stebbing, 1900b, p. 653 ; Verhoeff, 1926, p. 357 (*"lifouensis"*).
(Type locality, New Caledonia.)

Cubaris suteri CHILTON : Chilton, 1915a, p. 425. (Probably a *Sphaerillo*.)
(Type locality, Auckland, New Zealand)

Genus ECHINODILLO Jackson, 1933

(Type, *Echinodillo montanum* Jackson)

Echinodillo montanum JACKSON : Jackson, 1933b, p. 159.
(Type locality, Marquesas [Uahuka].)

Genus EMYDODILLO Verhoeff, 1926

(Type, *Emydodillo testudo* Verhoeff)

Emydodillo testudo VERHOEFF : Verhoeff, 1926, p. 264.
(Type locality, New Caledonia.)

Genus HAWAIODILLO Verhoeff, 1926

(Type, *? Armadillo perkinsi* Dollfus)

Hawaiodillo frontalis (BUDDE-LUND) : Budde-Lund, 1904, p. 67 (*Spherillo*) ; Verhoeff, 1926, p. 256 (*Hawaiodillo*).
Synonym : *Armadillo Danae* Dollfus, 1900, p. 522.
(Type locality, Hawaii [Kauai].)

Hawaiodillo perkinsi (DOLLFUS) : Dollfus, 1900, p. 522 (*Armadillo*) ; Budde-Lund, 1904, p. 67 (*Spherillo*) ; Verhoeff, 1926, p. 256 (*Hawaiodillo*).
(Type locality, Hawaii [Maui].)

the British Museum (Natural History) from widely spread localities suggests that the points of difference cited are not sufficiently constant to justify their separation.

Hawaiodillo sharpi (DOLLFUS): Dollfus, 1900, p. 523 (*Armadillo*); Budde-Lund, 1904, p. 67 (*Spherillo*); Verhoeff, 1926, p. 256 (*Hawaiodillo*).
(Type locality, Hawaii [Kauai].)

Genus MELANESILLO Verhoeff, 1938

(Type, *Sphaerillo hebridarum* Verhoeff)

Melanesillo hebridarum (VERHOEFF): Verhoeff, 1926, p. 297 (*Sphaerillo*); Herold, 1931, p. 321 (*Lobodillo*); Verhoeff, 1938, p. 1 (*Melanesillo*).
(Type localities, New Hebrides; Banks Islands.)

Melanesillo bocki VERHOEFF: Verhoeff, 1938, p. 4.
(Type locality, Marshall Islands [Jaluit].)

Melanesillo scamnorum VERHOEFF: Verhoeff, 1938, p. 4.
(Type locality, Fiji [Viti Levu].)

Genus MERULANA Budde-Lund, 1913

(Type, *Armadillo rugosus* Budde-Lund)

Merulana canaliculatus (BUDDE-LUND): Budde-Lund, 1904, p. 74 (*Spherillo*); Chilton, 1910b, p. 290 (*Cubaris*); Budde-Lund, 1913, p. 65 (*Merulana*); Chilton, 1925a, p. 319.
Synonym: *Armadillo speciosus* Chilton (not Dana), 1906b, p. 273.
(Type locality, Chatham Islands.)

Merulana chathamensis (BUDDE-LUND): Budde-Lund, 1904, p. 75 (*Spherillo*); Chilton, 1910b, p. 290 (*Cubaris*); Budde-Lund, 1913, p. 65.
Synonyms: *Armadillo speciosus* Chilton, 1901, p. 146 (not Dana); Budde-Lund, 1904, p. 75.
(Type locality, Chatham Islands.)

Merulana exilis (BUDDE-LUND): Budde-Lund, 1885, p. 288 (*Armadillo*); 1904, p. 76 (*Spherillo*).
(Type locality, New Caledonia [Noumea].)

Merulana noduligera VERHOEFF: Verhoeff, 1926, p. 306.
(Type localities, New Caledonia, Loyalty Islands.)

Merulana translucida (BUDDE-LUND): Budde-Lund, 1885, p. 290 (*Armadillo*); 1904, p. 76 (*Spherillo*); Verhoeff, 1926, p. 304 (*Merulana*). *M. translucida* var. *translucida* Verhoeff, 1926, p. 306. *M. translucida* var. *gracilior* Verhoeff, 1926, p. 306.
Synonym: *? Pyrgoniscus cinctutus* Kinahan, 1859, p. 199.
(Type localities, New Caledonia, Loyalty Islands.)

Genus MERULANELLA Verhoeff, 1926

(Type, *Merulanella carinata* Verhoeff)

Merulanella carinata VERHOEFF: Verhoeff, 1926, p. 308.
(Type locality, New Caledonia.)

Merulanella dollfusi (STEBBING) : Stebbing, 1900b, p. 654 (*Cubaris*) ; Verhoeff, 1926, p. 357.
   (Type locality, Loyalty Islands.)

Merulanella wahrbergi VERHOEFF: Verhoeff, 1926, p. 309.
   (Type locality, New Caledonia.)

Genus MESODILLO Verhoeff, 1926

(Type, *Mesodillo eremitus* Verhoeff)

Mesodillo eremitus VERHOEFF: Verhoeff, 1926, p. 294.
   (Type locality, New Caledonia.)

Genus OCHETODILLO Verhoeff, 1926

(Type, *Ochetodillo sulcatus* Verhoeff)

Ochetodillo sulcatus VERHOEFF: Verhoeff, 1926, p. 271.
   (Type locality, Humboldt Mountains, New Caledonia.)

Genus ORODILLO Verhoeff, 1926

(Type, *Orodillo collaris* Verhoeff)

Orodillo collaris VERHOEFF: Verhoeff, 1926, p. 291.
   (Type locality, New Caledonia.)

Genus SCHISMADILLO Verhoeff, 1926

(Type, *Schismadillo rouxi* Verhoeff)

Schismadillo rouxi VERHOEFF: Verhoeff, 1926, p. 272.
   (Type locality, Canala Mountains, New Caledonia.)

Genus SPHERILLO Dana, 1853 [7]

(Type, *? Spherillo vitiensis* Dana)

Spherillo Budde-Lund, 1904

Sphaerillo Verhoeff (ex parte), 1926

(Type, *Spherillo danae* Heller)

Spherillo albospinosus (DOLLFUS) : Dollfus, 1900, p. 521 (*Armadillo*) ; Budde-Lund, 1904, p. 54 (*Spherillo*).
   Hawaii (Oahu, Kauai).
   (Type locality, Hawaii [Oahu].)

---

[7] All species which fall under *Sphaerillo* Verhoeff are distinguished by that spelling from those which were included under *Spherillo* Dana by Budde-Lund and will ultimately find a place in other new or existing genera. (See introduction.)

Spherillo ambitiosus (Budde-Lund): Budde-Lund, 1879, p. 7 (*Armadillo*);
1885, p. 34 (*Armadillo*); Chilton, 1901, p. 144 (*Armadillo*); Budde-Lund,
1904, p. 63 (*Spherillo*); Chilton, 1910b, p. 289 (*Cubaris*).
(Type locality, New Zealand.)
"Common over North Island and in South Island down west coast as far as
Daggs Sound." (Chilton.)

Spherillo bipunctatus Budde-Lund: Budde-Lund, 1904, p. 62; Chilton, 1910b,
p. 289 (*Cubaris*).
(Type locality, Lyttelton, New Zealand.)
"One male specimen." (Budde-Lund.)

Sphaerillo brevis (Budde-Lund): Budde-Lund, 1904, p. 93 (*Spherillo*); Chil-
ton, 1910b, p. 290 (*Cubaris*).
(Type locality, Auckland.)
"One specimen." (Budde-Lund.)

Spherillo carinulatus Budde-Lund: Budde-Lund, 1904, p. 54.
Synonym: *Armadillo albospinosus* Dollfus, 1900, p. 521, ♀.
(Type locality, Hawaii [Kauai].)

Sphaerillo danae (Heller): Heller, 1865, p. 134 (*Spherillo*); Budde-Lund,
1885, p. 39 (*Armadillo*); Filhol, 1885, p. 440 (*Spherillo*); Thomson and
Chilton, 1886, p. 159 (*Spherillo*); Chilton, 1901, p. 145 (*Armadillo*);
Budde-Lund, 1904, p. 94 (*Spherillo*); Chilton, 1910b, p. 290 (*Cubaris*).
Synonym: *Armadillo inconspicuus* Miers, 1876a, p. 225; 1876b; p. 95; Filhol,
1885, p. 439; Thomson and Chilton, 1886, p. 159.
New Zealand, North Island, more rare in South; Kapiti Island, Auckland.
(Type locality, Auckland.)

Spherillo dispersus Budde-Lund: Budde-Lund, 1904, p. 70.
(Type locality, Bismarck Archipelago?)

Spherillo erinaceus (Budde-Lund): Budde-Lund, 1879, p. 7; 1885, p. 36 (*Arma-
dillo*); 1904, p. 54 (*Spherillo*).
(Type locality, Samoa [Upolu].)

Sphaerillo (Sphaerillo) fissus Verhoeff: Verhoeff, 1926, p. 299.
(Type locality, New Caledonia.)

Spherillo hamiltoni (Chilton): Chilton, 1901, p. 148 (*Armadillo*); Budde-
Lund, 1904, p. 54 (*Spherillo*); Chilton, 1910b, p. 289 (*Cubaris*).
(Type locality, New Zealand.)

Spherillo hawaiensis Dana: Dana, 1853, p. 722; Budde-Lund, 1885, p. 39
(*Armadillo*); Dollfus, 1900, p. 521 (*Armadillo*); Budde-Lund, 1904, p. 57
(*Spherillo*).
Synonyms: *Armadillo bidens* Budde-Lund, 1885, p. 18 (♂).
Armadillo australis Budde-Lund, 1885, p. 33 (♀).
Hawaii (Oahu, Lanai, Kauai, Molokai).
(Type locality, "Sandwich Islands.")

Sphaerillo (Xestodillo) lifouensis Verhoeff: Verhoeff, 1926, p. 301; *S. lifouen-
sis* var. *ambrymensis,* Verhoeff, 1926, p. 302 (New Hebrides.)
(Type locality, Loyalty Islands.)

Spherillo macmahoni (CHILTON) : Chilton, 1901, p. 149 (*Armadillo*) ; Budde-Lund, 1904, p. 56 (*Spherillo*) ; Chilton, 1910b, p. 289 (*Cubaris*). (Probably a *Sphaerillo*.)

(Type locality, Marlborough, New Zealand.)

Spherillo marginatus BUDDE-LUND: Budde-Lund, 1904, p. 65; Chilton, 1910b, p. 289 (*Cubaris*).

(Type locality, Auckland, New Zealand.)

"One female specimen."

Spherillo melanurus (DOLLFUS) : Dollfus, 1887, p. 1 (*Armadillo*) ; Budde-Lund, 1904, p. 94 (*Spherillo*).

(Type locality, New Caledonia.)

Spherillo monolinus DANA: Dana, 1853, p. 719; Heller, 1865, p. 135; Budde-Lund, 1885, p. 39 (*Armadillo*) ; Filhol, 1885, p. 440; Thomson and Chilton, 1886, p. 159 (*Spherillo*) ; Chilton, 1901, p. 148 (*Armadillo*) ; Budde-Lund, 1904, p. 68 (*Spherillo*) ; Chilton, 1910b, p. 290 (*Cubaris*).

Synonym: *Armadillo Aucklandicus* Budde-Lund, 1885, p. 40; 1904, p. 69 (*Spherillo*).

New Zealand, "Whykare River near Bay of Islands."

(Type locality, Auckland, New Zealand.)

Sphaerillo (Sphaerillo) montivagus (BUDDE-LUND) : Budde-Lund, 1879, p. 7 (*Armadillo*) ; 1885, p. 35 (*Armadillo*) ; 1904, p. 89 (*Spherillo*) ; Jackson, 1933a, p. 90; 1933b, p. 155; 1938, p. 190.

Samoa (Upolu) ; Tuamotus (Mangareva, Henderson) ; Australs (Rapa, Raivavae, Tubuai) ; Pitcairn; Society Islands (Tahiti) ; Tonga; Marquesas (Hivaoa, Uahuka, Uapou) ; Bismarck Archipelago (Ruk).

(Type locality, Samoa [Upolu].)

Sphaerillo (Xestodillo) marquesarum (JACKSON) : Jackson, 1933a, p. 90 (*Spherillo*) ; 1933b, p. 156; 1938, p. 191: var. *australis* Jackson, 1938, p. 191.

Marquesas (Uapou) ; Society Islands (Tahiti, Moorea) ; Tuamotus (Mangareva, Henderson) ; Pitcairn; Australs (Raivavae, Rurutu, Rimatara).

(Type locality, Marquesas [Uapou].)

Sphaerillo pictus (HELLER) : Heller, 1865, p. 135 (*Spherillo*) ; Budde-Lund, 1885, p. 40 (*Armadillo*) ; 1904, p. 95 (*Spherillo*).

(Type locality, "Taiti" Island.)

Sphaerillo (Xestodillo) politus VERHOEFF: Verhoeff, 1926, p. 302.

(Type locality, New Caledonia.)

Sphaerillo (Sphaerillo) pygmaeus VERHOEFF: Verhoeff, 1926, p. 296; Jackson, 1933b, p. 156.

New Caledonia; Marquesas (Nukuhiva).

(Type locality, New Caledonia.)

Spherillo ruficornis BUDDE-LUND: Budde-Lund, 1885, p. 283 (*Armadillo*) ; 1904, p. 86 (*Spherillo*).

(Type locality, New Caledonia.)

Spherillo rufomarginatus Budde-Lund: Budde-Lund, 1904, p. 64; Chilton, 1910b, p. 289 (*Cubaris*).
(Type locality, New Zealand.)
"One female specimen was taken at Taranga [? Tauranga]."

Spherillo rugulosus (Miers): Miers, 1876a, p. 225 (*Cubaris*); 1876b, p. 96 (*Cubaris*); Chilton, 1883a, p. 73 (*Cubaris*); Budde-Lund, 1885, p. 40 (*Armadillo*); Thomson and Chilton, 1886, p. 158 (*Cubaris*); Chilton, 1901, p. 147 (*Armadillo*); Budde-Lund, 1904, p. 65 (*Spherillo*); Chilton, 1909a, p. 668 (*Cubaris*); 1910b, p. 290 (*Cubaris*); Stephensen, 1927, p. 372 (*Cubaris*).
New Zealand, "very abundant on South Island" (Chilton); Auckland and Campbell Islands.
(Type locality, New Zealand.)

Sphaerillo setaceus (Budde-Lund): Budde-Lund, 1904, p. 89 (*Spherillo*); Chilton, 1910b, p. 290 (*Cubaris*).
(Type locality, Auckland.)
One specimen.

Sphaerillo societatis (Maccagno): Maccagno, 1932, p. 1 (*Spherillo*).
(Type locality, Society Islands [Moorea].)

Spherillo speciosus (Dana): Dana, 1853, p. 718 (*Armadillo*); Miers, 1876b, p. 95 (*Armadillo*); Budde-Lund, 1885, p. 39 (*Armadillo*); Thomson and Chilton, 1886, p. 159 (*Armadillo*); not Chilton, 1901, p. 146; Budde-Lund, 1904, p. 69 (*Spherillo*); Chilton, 1910b, p. 290 (*Cubaris*). See *Merulana chathamensis*.
(Type locality, New Zealand, near Bay of Islands.)

Spherillo spicatus Jackson: Jackson, 1927b, p. 4.
(Type locality, Samoa [Upolu].)

Spherillo spinosus Dana: Dana, 1853, p. 723; Budde-Lund, 1885, p. 39 (*Armadillo*); Thomson and Chilton, 1886, p. 159 (*Spherillo*); Chilton, 1901, p. 150 (*Armadillo*); Budde-Lund, 1904, p. 54 (*Spherillo*); Chilton, 1910b, p. 289 (*Cubaris*); Verhoeff, 1926, p. 274 (? *Schismadillo*).
(Type locality, New Zealand, near Bay of Islands.)

Spherillo squamatus Budde-Lund: Budde-Lund, 1904, p. 61; Chilton, 1910b, p. 289 (*Cubaris*).
(Type locality, New Zealand.)
"One female from Lyttelton, near Christchurch."

Spherillo tarangensis Budde-Lund: Budde-Lund, 1904, p. 67; Chilton, 1910b, p. 290 (*Cubaris*).
New Zealand: Taranga [? Tauranga] and Lyttelton.
(Type locality, Taranga and Lyttelton, New Zealand.)

Spherillo testudinalis (Budde-Lund): Budde-Lund, 1879, p. 7 (*Armadillo*); 1885, p. 29 (*Armadillo*); 1904, p. 80 (*Spherillo*); 1908, p. 269; 1912, p. 377 (*Cubaris*); Searle, 1914, p. 367; Jackson, 1927b, p. 3; 1933b, p. 156; 1938, p. 190.

Synonyms: *Armadillo samoensis* Budde-Lund, 1885, p. 30; 1904, p. 80.
            Armadillo tongensis Budde-Lund, 1885, p. 284; 1904, p. 80.
         ? *Armadillidium pacificum* Borradaile, 1900, p. 796; Searle, 1914,
            p. 369.
Samoa (Upolu); Tonga; Bismarck Archipelago (Ruk, Matapi); Cook Islands
    (Rarotonga); Caroline Islands; Marianas; Ellice Islands; Fiji; Mar-
    quesas (Nukuhiva); Tuamotus (Mangareva); Australs (Raivavae,
    Tubuai); Society Islands (Tahiti, Raiatea, Moorea, Tahaa, Mehetia
    [Maitea]).
(Type locality, Nicobar Island, Bay of Bengal.)

Spherillo vitiensis Dana: Dana, 1853, p. 721; Budde-Lund, 1885, p. 39 (*Arma-
    dillo*); *not* Dollfus, 1890b, p. 2 (*Armadillo*); Budde-Lund, 1904, p. 69
    (*Spherillo*).
(Type locality, Fiji [Vanua Levu].)

Sphaerillo (Xestodillo) zebricolor (Stebbing): Stebbing, 1900b, p. 656 (*Cu-
    baris*); Verhoeff, 1926, p. 300 (*Sphaerillo*).
(Type localities, New Caledonia, Loyalty Islands.)

Genus TRIDENTODILLO Jackson, 1933

(Type, *Tridentodillo squamosus* Jackson)

Tridentodillo squamosus Jackson: Jackson, 1933b, p. 161.
(Type locality, Marquesas [Nukuhiva].)

Subfamily ARMADILLIDINAE

Genus ARMADILLIDIUM Brandt, 1830

(Type, *Armadillo vulgare* Latreille.)

Armadillidium vulgare (Latreille): Latreille, 1804, p. 48 (*Armadillo*); Chil-
    ton, 1901, p. 142; 1905, p. 431.
For further references and synonymy see Budde-Lund, 1885, p. 67, and Van
    Name, 1936, p. 276.
New Zealand.
(Type locality, Europe.)

Suborder PHREATOICIDEA
Family PHREATOICIDAE
Genus PHREATOICUS Chilton, 1882

(Type, *Phreatoicus typicus* Chilton, 1882)

Phreatoicus typicus Chilton: Chilton, 1883b, p. 87; Thomson and Chilton, 1886,
    p. 151; Stebbing, 1888, pp. 543 and 587; 1893, p. 388; Chilton, 1894, p. 196;
    Sheppard, 1927, p. 109.
New Zealand.
(Type locality, Eyreton and Ashburton, New Zealand [in wells].)

Phreatoicus kirkii CHILTON: Chilton, 1906c, p. 275; Sheppard, 1927, p. 110.
(Type locality, "In a fresh water lagoon on Ruapuke Island.")
Var. *dunedinensis* Chilton, 1906c, p. 276.
(Type locality, in streams, Mosgiel and Woodhaugh, near Dunedin, New Zealand.)

Phreatoicus assimilis CHILTON: Chilton, 1894, p. 186; Sheppard, 1927, p. 111.
(Type locality, in wells at Winchester, near Canterbury, New Zealand.)

Suborder VALVIFERA

Family IDOTHEIDAE

Subfamily MESIDOTEINAE

Genus AUSTRIDOTEA Nicholls, 1937

(Type, *Austridotea annectens* Nicholls, 1937)

Austridotea (Austridotea) annectens NICHOLLS: Nicholls, 1937, p. 118.
(Type locality, Stewart Island.)

Austridotea (Austridotea) benhami NICHOLLS: Nicholls, 1937, p. 123.
Synonyms: *Idotea lacustris* var. β: Chilton, 1891, p. 131; 1892, p. 263; 1909a, p. 658.
Pentidotea lacustris (part): Collinge, 1916, p. 154.
Otago Peninsula, New Zealand, Campbell Island ?.
(Type locality, "mountain streams around Port Chalmers and Dunedin," Otago Peninsula, New Zealand.)

Austridotea (Notidotea) lacustris (THOMSON)[8]; Thomson, 1879c, p. 251 (*Idotea*); Miers, 1881, p. 39 (*Idotea*); Thomson and Chilton, 1886, p. 156 (*Idotea*); Chilton, 1890, p. 194 (*Idotea*); *I. lacustris* var. *a* Chilton, 1892, p. 263; Chilton, 1909a, p. 658; Collinge, 1916, p. 154 (*Pentidotea*); Van Name, 1936, p. 451 (*Pentidotea*); Nicholls, 1937, p. 125 (*Notidotea*).
Dunedin, Waitati, Mihiwaka, New Zealand.
(Type locality, Dunedin, New Zealand.)

Suborder FLABELLIFERA

Family ANTHURIDAE

Genus CRUREGENS Chilton, 1882

(Type, *Cruregens fontanus* Chilton, 1882)

Cruregens fontanus CHILTON: Chilton, 1882, p. 175; 1883b, p. 88; Thomson and Chilton, 1886, p. 152; Chilton, 1894, p. 211.
Eyreton, North Canterbury; Leeston; Winchester, South Canterbury (in wells).
(Type locality, Eyreton, North Canterbury, New Zealand.)

---

[8] "*I. lacustris* G. M. T. is in all probability not restricted to, but merely tolerant of, fresh water." Nicholls, 1937.

Family SPHAEROMIDAE

Subfamily SPHAEROMINAE

Genus PARAVIREIA Chilton, 1925

(Type, *Paravireia typicus* Chilton)

Paravireia typicus Chilton: Chilton, 1925b, p. 321.
(Type locality, Chatham Islands.)

REFERENCES

Arcangeli, A.

  1927. Isopodi terrestri raccolti nell'Estremo Oriente. Boll. Lab. Zool., Portici, vol. 20, pp. 211-269, figs. 1-22.

  1933. Isopodi terrestre delle Isole Samoa. . . . Boll. Mus. Zool. Anat. Comp. Torino, vol. 43, pp. 25-33, 4 pls.

Barnard, K. H.

  1932. Contributions to the crustacean fauna of South Africa. No. 11. Terrestrial Isopoda. Ann. South African Mus., vol. 30, pt. 2, pp. 179-388, figs. 1-80.

Bate, C. Spence, and Westwood, J. O.

  1868. A history of the British sessile-eyed Crustacea, vol. 2, lvi + 536 pp. London.

Borradaile, L. A.

  1900. On some crustaceans from the South Pacific. Pt. 5, Arthrostracans and barnacles. Proc. Zool. Soc. London, pp. 795-799, pl. 51.

Brandt, J. F.

  1833. Conspectus Monographiae Crustaceorum Oniscodorum Latreillii. Bull. Soc. Imp. Nat. Moscou, vol. 6, pp. 171-193, pl. 4. (Also published with separate paging.)

Budde-Lund, G.

  1879. Prospectus generum specierumque Crustaceorum Isopodum terrestrium, pp. 1-10. Copenhagen.

  1885. Crustacea Isopoda Terrestria per Familias et Genera et Species descripta, pp. 1-319. Hávniae.

  1904. A revision of "Crustacea Isopoda Terrestria" with additions and illustrations. 2. Spherilloninae. 3. Armadillo. Pp. 33-144, pls. 6-10. Copenhagen.

  1906. Die Landisopoden der Deutschen Südpolar-Expedition 1901-1903. Mit Diagnosen verwandter Arten. Deutsche Südpolar-Expedition 1901-1903, bd. 9, heft 2, pp. 69-92, pls. 3-4.

  1908. Ispoda von Madagaskar und Ostafrika. *In* Voeltzkow, Reise in Ostafrika in den Jahren 1903-1905, bd. 2, pp. 265-308, pls. 12-18.

  1912. Terrestrial Isopoda, particularly considered in relation to the distribution of the southern Indo-Pacific species. *In* Report Percy Sladen Trust Exped. Trans. Linn. Soc. London (Zool.), vol. 15, pp. 367-394, pls. 20-22. (Revised and footnotes added by Rev. T. R. R. Stebbing.)

  1913. Über einige Oniscoideen von Australien, nachgelassenes Fragment. Jahrb. Hamburg Wiss. Anst., vol. 30, beiheft 2, pp. 65-72, figs. 1-8, 1 pl.

CHILTON, CHARLES

1882. On some subterranean Crustacea. Trans. New Zealand Inst., vol. 14 (1881), pp. 174-180, pls. 10, 11.

1883a. Further additions to our knowledge of the New Zealand Crustacea. Trans. New Zealand Inst., vol. 15 (1882), pp. 69-86, pls. 1-3.

1883b. Notes on, and a new species of subterranean Crustacea. Trans. New Zealand Inst., vol. 15 (1882), pp. 87-92, pl. 4.

1883c. Additions to the isopoden fauna of New Zealand. Trans. New Zealand Inst., vol. 15 (1882), pp. 145-150, 1 pl.

1886. A new species of *Philygria.* Trans. New Zealand Inst., vol. 18 (1885), pp. 159-161, pl. 5.

1890. Revision of the New Zealand Idoteidae. Trans. New Zealand Inst., vol. 22 (1889), pp. 189-204.

1891. General notes. New Zealand Journ. Sci. (new issue), vol. 1, No. 3, pp. 131-132.

1892. Notes on some New Zealand Amphipoda and Isopoda. Trans. New Zealand Inst., vol. 24 (1891), pp. 258-269.

1894. The subterranean Crustacea of New Zealand: with some general remarks on the fauna of caves and wells. Trans. Linn. Soc. London (Zool.), vol. 6, pt. 2, pp. 163-284, pls. 16-23.

1901. The terrestrial Isopoda of New Zealand. Trans. Linn. Soc. London (Zool.), vol. 8, pt. 4, pp. 99-152, pls. 11-16.

1905. Notes on the distribution of some species of terrestrial Isopoda introduced into Australasia. Ann. Mag. Nat. Hist., vol. 16, ser. 7, pp. 428-432.

1906a. Note on the occurrence of *Metoponorthus pruinosus,* Brandt, in New Zealand. Trans. New Zealand Inst., vol. 38 (1905), pp. 64-65.

1906b. List of Crustacea from the Chatham Islands. Trans. New Zealand Inst., vol. 38 (1905), pp. 269-273.

1906c. Description of a species of *Phreatoicus* from the surface waters of New Zealand. Trans. New Zealand Inst., vol. 38 (1905), pp. 274-276.

1909a. The Crustacea of the Subantarctic Islands of New Zealand. The Subantarctic Islands of New Zealand, vol. 2, art. 26, pp. 601-671, figs. 1-19. Wellington, New Zealand.

1909b. The biological relations of the Subantarctic Islands of New Zealand: summary of results. The Subantarctic Islands of New Zealand, vol. 2, art. 35, pp. 793-807. Wellington, New Zealand.

1910a. On an isopod inhabiting ants' nests in New Zealand. Trans. New Zealand Inst., vol. 42 (1909), pp. 190-192.

1910b. Additions to the terrestrial Isopoda of New Zealand. Trans. New Zealand Inst., vol. 42 (1909), pp. 286-291.

1911. The Crustacea of the Kermadec Islands. Trans. New Zealand Inst., vol. 43 (1910), pp. 544-573, figs. 1-4.

1915a. Some terrestrial Isopoda from New Zealand and Tasmania, with description of a new genus. Journ. Linn. Soc. London (Zool.), vol. 32, pp. 417-427, pls. 36-37.

1915b. *Deto,* a subantarctic genus of terrestrial Isopoda. Journ. Linn. Soc. London (Zool.), vol. 32, pp. 435-456, pls. 39, 40.

1917. A new tuberculate terrestrial isopod from New Zealand. Ann. Mag. Nat. Hist., vol. 19, ser. 8, pp. 327-329, pl. 13.

1922. Note on the isopod known as *Geoligia perkinsi* Dollfus (Crust.). Proc. Hawaiian Ent. Soc., vol. 5, No. 1, pp. 83-86.

1924a. Fauna of the Chilka Lake. Tanaidacea and Isopoda. Mem. Indian Mus., vol. 5, No. 12, pp. 875-895, figs. 1-10, pl. 60.

1924b. Occurrence in South America of the shore isopod *Ligia novae-zealandiae* Dana. New Zealand Journ. Sci. and Techn., vol. 6, Nos. 5 and 6, pp. 287-288.

1925a. Some Amphipoda and Isopoda from the Chatham Islands. Rec. Canterbury Mus., vol. 2, pp. 317-320.

1925b. A new genus of Isopoda (Family Sphaeromidae). Rec. Canterbury Mus., vol. 2, pp. 321-326, pls. 45-47.

COLLINGE, W. E.

1916. Some remarks upon the structure and generic position of *Idotea lacustris* Thomson. Journ. Zool. Res., London, vol. 1, pp. 153-157, pl. 6.

CUVIER, G.

1829. Le règne animal, édit. 2, tom. 4, par P. A. Latreille. Paris.

1849. Le règne animal, édition 3 accompagnée de planches gravées. Vol. 8, Les Crustacés par Milne-Edwards. Paris.

DANA, J. D.

1853. Isopoda. *In* United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U.S.N., vol. 14, Crustacea, pt. 2, pp. 696-805. Atlas, pls. 46-53 (1855).

1856. Catalogue and descriptions of Crustacea collected in California by Dr. John Le Conte. Proc. Philadelphia Acad. Nat. Sci., vol. 7, pp. 175-177.

DESMAREST, A. G.

1825. Considérations générales sur la classe des crustacés. Pp. xix + 446, pls. 1-56. Paris.

DOLLFUS, ADRIEN

1887. Diagnoses d'espèces nouvelles . . . des Armadilliens. Bull. Soc. Études Sci., vol. 9, pp. 1-7.

1889. Sur quelques isopodes du Musée de Leyde. Notes Leyden Mus., vol. 11, pp. 91-94, pl. 5.

1890a. Note au sujet des isopodes terrestres du *Challenger*. Bull. Soc. Études Sci. Paris, vol. 12, p. 71.

1890b. Isopodes terrestres du *Challenger*. Bull. Soc. Études Sci. Paris, vol. 12, pp. 63-70, 2 pls. (Also reprinted, paged 1-8.)

1893. Sur la distribution du genre *Ligia* Fabr. Feuille Natural., vol. 24, No. 3, pp. 23-26, figs. 1-4.

1898. Isopodes Terrestres des Indes Neerlandaises. M. Weber, Zool. Ergebn. einer Reise in Niederländisch-OstIndien, vol. 4, pp. 357-382, 3 pls. Leiden.

1900. Crustacea Isopoda. Fauna Hawaiiensis, vol. 2, pt. 5, pp. 521-526, pl. 20 (vol. 2, 1899-1910 was issued in 1913).

ESCHSCHOLTZ, F. FRID
    1823. Animalia tetracera et myriapoda exotica. Mem. Soc. Imp. Nat.
        Moscou, vol. 6, pt. 2, pp. 111-114.
FABRICIUS, J. C.
    1793. Entomologia systematica emendata et aucta. Vol. 2, viii + 519 pp.
        Hafniae.
    1798. Supplementum entomologiae systematicae. Hafniae.
FILHOL, H.
    1885. Mission de l'île Campbell. Rec. Mémoires . . . , vol. 3, pt. 2, Crus-
        tacea, chap. 7, pp. 349-516, pls. 38-55. Paris (Inst. France, Acad.
        Sci.).
GUÉRIN, F. E.
    1836. *Deto*. Mag. Zool., vol. 6, classe 7, pl. 14 (rectius 21).
HELLER, C.
    1865.[9] Crustaceen in Reise der Oesterreichischen Fregatte Novara um die
        Erde in den Jahren 1857, 1858, 1859. Zoologischer Theil., bd. 2,
        abt. 3, pp. 280, 25 pls. Vienna.
HEROLD, W.
    1931. Land-Isopoden von den Sunda-Inseln. Arch. Hydrobiol., suppl. bd.
        9, heft 2, pp. 306-393, figs. 1-193.
JACKSON, HAROLD GORDON
    1922. A revision of the isopod genus *Ligia* (Fabricius). Proc. Zool. Soc.
        London, pp. 683-703, pls. 1, 2.
    1927a. A new subgenus of *Ligia,* with further observations on the genus.
        Ann. Mag. Nat. Hist., vol. 19, ser. 9, pp. 129-136, pl. 2.
    1927b. Isopoda terrestria. *In* Insects of Samoa. Brit. Mus. (Nat. Hist.),
        pt. 8, fasc. 1, pp. 1-11, pls. 1, 2.
    1933a. *Porcellio (Heminagara) tahitiensis,* new subgenus and species, and
        other Tahitian terrestrial isopods. Bull. Bishop Mus., Honolulu,
        No. 113, pp. 87-90, fig. 1. (Pacific Ent. Surv. Publ. 6, art. 17.)
    1933b. Marquesan terrestrial Isopoda. Bull. Bishop Mus., Honolulu, No. 114,
        pp. 145-162, figs. 1-6. (Pacific Ent. Surv. Publ. 7, art. 10.)
    1936. Terrestrial isopods from Malaysia. Bull. Raffles Mus., Singapore,
        No. 12, pp. 77-87, figs. 1-4.
    1938. Terrestrial isopods of southeastern Polynesia. Occ. Papers B. P.
        Bishop Mus., vol. 14, No. 10, pp. 167-192, figs. 1-10. (Mangarevan
        Exped. Publ. 26.)
KINAHAN, J. R.
    1859. On the genus *Platyarthus* Brandt; with notices of allied undescribed
        genera. Proc. Dublin Univ. Zool.-Bot. Assoc., vol. 1, pt. 2, pp.
        188-201.
KOCH, C. L.
    1847. System der Myriapoden mit den Verzeichnissen und Berichtigungen
        zu Deutschlands Crustacean, Myriapoden, und Arachniden.
        Regensburg.

---

[9] "The year 1865 is appended to the several plates, but the publication of the volume took place in 1866." Spence Bate, *Challenger* Macrura, 1888, p. 196.

LATREILLE, P. A.
    1804. Histoire naturelle des crustacés et des insectes. Vol. 7, 413 pp., pls.
        58-66.
    1806. Genera crustáceorm et insectorum . . . Vol. I. Parisiis et Argen-
        torati.
MACCAGNO, T.
    1931. *Ligia porteri* Macc., nuova specie di isopodo terrestre del Cile. Boll.
        Zool. Napoli, vol. 2, pp. 151-157, pl. 3.
    1932. Isopodi Terrestri delle Isole della Società. Boll. Mus. Zool. Anat.
        Comp. Torino, vol. 42, No. 20, pp. 1-7, 20 figs.
MIERS, EDWARD J.
    1876a. Description of some new species of Crustacea, chiefly from New
        Zealand. Ann. Mag. Nat. Hist., vol. 17, ser. 4, pp. 218-229.
    1876b. Oniscoidea. *In* Catalogue of the stalk- and sessile-eyed Crustacea of
        New Zealand, pp. 94-103.
    1877a. Crustacea. *In* Gunther, Account of the zoological collection made
        during the visit of H.M.S. *Peterel* to the Galapagos Islands. Proc.
        Zool. Soc. London, pp. 73-75, 1 pl.
    1877b. On a collection of Crustacea, Decapoda, and Isopoda chiefly from
        South America, with descriptions of new genera and species. Proc.
        Zool. Soc. London, pp. 653-679, pls. 66-69.
    1881. Revision of the Idoteidae, a family of sessile-eyed Crustacea. Journ.
        Linn. Soc. (Zool.), vol. 16, No. 89, pp. 1-88, pls. 1-3.
MILNE-EDWARDS, H.
    1840. Isopoda. *In* Histoire Naturelle des Crustacés, vol. 3, pp. 115-283, pls.
        31-33. Paris.
NICHOLLS, G. E.
    1937. On the freshwater Idoteidae of New Zealand. Ann. Mag. Nat. Hist.,
        vol. 19, ser. 10, pp. 113-136, 18 figs.
NICOLET, H.
    1849. Isopodes. *In* Gay, Historia fisica y politica de Chile, Zool., vol. 3,
        pp. 256-287; atlas, pls. 3, 4, Crust. (1854).
PANNING, A.
    1924. Isopoda. *In* Michaelsen, Beitrage . . . Land-v. Süsswasserfauna
        Deutsch-Südwestafrikas, vol. 2, lief. 3, pp. 169-201, figs. 1-11.
PERTY, M.
    1830-34. Delectus animalium articulatorum quae in itinere per Braziliam
        annis 1817-1823 collegerunt J. B. de Spix et C. F. Ph. de Martius,
        pp. 1-224, pls. 1-40. Monachii. (Isopods pp. 211, 212, pl. 40.)
PFEFFER, G.
    1889. Übersicht der von Herrn Dr. Franz Stuhlmann in Ägypten, auf
        Sansibar . . . gesammelten . . . Krebse. Jahrb. Hamburg Wiss.
        Anst., vol. 6, pt. 2 (1888), pp. 1-36.
RICHARDSON, HARRIET
    1905. A monograph on the Isopods of North America. U. S. Nat. Mus.
        Bull. 54, liii + 727 pp., figs. 1-740.
ROUX, POLYDORE
    1828. Crustacés de la méditerranée et de son littoral. Pp. 1-176, pls. 1-45.
        Marseille.

SAVIGNY, J. C.
　　1827. Description de l'Egypte. Histoire naturelle Zoologie. Planches par
　　　　　J. C. Savigny. Vol. 12, Crust., pp. 1-13. Paris, 1826. Texte. Expli-
　　　　　cation sommaire des planches de Crustacés de l'Egypte et de la
　　　　　Syrie publièes par J. C. Savigny et par V. Audouin, vol. 22, p. 249.
　　　　　Paris, 1827.

SEARLE, H. RICHARDSON
　　1914. Isopoda. *Albatross* Exped. 1899-1900 and 1904-1905. Bull. Mus.
　　　　　Comp. Zool. Harvard, vol. 58, No. 8, pp. 361-372, figs. 1-16.

SHEPPARD, EDITH M.
　　1927. Revision of the family Phreatoicidae (Crustacea), with a description
　　　　　of two new species. Proc. Zool. Soc. London, pp. 81-124, figs. 1-7.

STEBBING, T. R. R.
　　1888. Report on the Amphipoda. . . . Rep. Sci. Res. H.M.S. *Challenger,*
　　　　　Zool., vol. 29, pp. 543 and 587.

　　1893. A history of Crustacea. xvii + 466 pp. New York.

　　1900a. On some crustaceans from the Falkland Islands collected by Mr.
　　　　　Rupert Vallentin. Proc. Zool. Soc. London, pp. 517-568, pls. 36-39.

　　1900b. On Crustacea brought by Dr. Willey from the South Seas. Willey's
　　　　　Zool. Results, pt. 5, pp. 605-690, pls. 64-74.

STEPHENSEN, K.
　　1927. Crustacea from the Auckland and Campbell Islands. Vidensk. Medd.
　　　　　Dansk. Naturh. Foren., vol. 83, pp. 289-390, figs. 1-33.

STIMPSON, WILLIAM
　　1857. Crustacea and Echinodermata of the Pacific shores of North America.
　　　　　Journ. Boston Soc. Nat. Hist., vol. 6, pp. 444-532, pls. 18-23.

THOMSON, G. M.
　　1879a. New Zealand Crustacea, with descriptions of new species. Trans.
　　　　　New Zealand Inst., vol. 11 (1878), pp. 230-247, pl. 10.

　　1879b. Description of new crustacean from the Auckland Islands. Trans.
　　　　　New Zealand Inst., vol. 11 (1878), pp. 249-250.

　　1879c. Description of a new species of isopodous crustacean (*Idotea*). Trans.
　　　　　New Zealand Inst., vol. 11 (1878), pp. 250, 251.

　　1892. Notes on Tasmanian Crustacea, with descriptions of new species.
　　　　　Proc. Roy. Soc. Tasmania, pp. 45-76, pls. 1-6 (reprint, pp. 1-32).

THOMSON, G. M., and CHILTON, CHARLES.
　　1886. Critical list of the Crustacea Malacostraca of New Zealand. Trans.
　　　　　New Zealand Inst. Zool., vol. 18 (1885), pp. 141-159.

VAN NAME, WILLARD G.
　　1936. The American land and fresh-water isopod Crustacea. Amer. Mus.
　　　　　Nat. Hist. Bull. 71, vii + 535 pp., figs. 1-323.

VERHOEFF, K. W.
　　1926. Isopoda Terrestria von Neu-Caledonien und den Loyalty-Inseln. Nova
　　　　　Caledonia, Zool., vol. 4, liv. 2, pp. 243-366, figs. 1-141.

　　1928a. Über einige Isopoden der zoologischen Staatssammlung in München.
　　　　　38. Isopoden-Aufsatz. Zool. Anz., vol. 76, heft 1/2, pp. 25-36, figs.
　　　　　1-16; heft 3/6, pp. 113-123, figs. 17-31.

1928b. Isopoden aus Formosa. 39. Isopoden-Aufsatz. Mitt. Zool. Mus. Berlin, bd. 14, heft 2, pp. 199-226, figs. 1-31.

1938. Über einige polynesische Oniscoideen von Prof. Sixten Bock's Pazifik-Expedition 1917-1918. Ark. Zool., vol. 30A, No. 16, pp. 1-14, figs. 1-21.

WAHRBERG, RAGNAR

1922a. Results of Dr. E. Mjöberg's Swedish scientific expeditions to Australia, 1910-1913, No. 30. Terrestre Isopoden aus Australien. Ark. Zool., vol. 15, No. 1, pp. 1-298, figs. 1-78.

1922b. Einige terrestre Isopoden von den Juan Fernandez Inseln. Skottsberg, C. The Natural History of Juan Fernandez and Easter Island, vol. 3, pp. 277-288, 4 text figs.

WHITE, A.

1847. List of the specimens of Crustacea in the collection of the British Museum. London.

INDEX

Generic and subgeneric names are in capitals.
Synonyms are in italics.

RECENT FORAMINIFERA FROM OLD PROVIDENCE ISLAND COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

(WITH TWO PLATES)

BY

JOSEPH A. CUSHMAN

Cushman Laboratory for Foraminiferal Research,
Sharon, Mass.

RECENT FORAMINIFERA FROM OLD PROVIDENCE ISLAND COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

(With Two Plates)

BY

JOSEPH A. CUSHMAN

Cushman Laboratory for Foraminiferal Research,
Sharon, Mass.

RECENT FORAMINIFERA FROM OLD PROVIDENCE ISLAND COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

By JOSEPH A. CUSHMAN

*Cushman Laboratory for Foraminiferal Research,
Sharon, Mass.*

(WITH TWO PLATES)

During the Presidential Cruise of 1938 collections were made at Old Providence Island in the Caribbean Sea. As no Foraminifera have been recorded from that particular area, it is interesting to note the occurrence of numerous species. The series of specimens of *Articulina cassis* (d'Orbigny) was noteworthy in showing the great variation that occurs in that species; a representative series of which is shown on our plate. Only a few of the species are figured. References to published figures, including the original reference, are given for each species. A few other species are represented by material too meager for definite specific determination. Nearly all the species were described by d'Orbigny in 1839 in his work on the Foraminifera of the shore sands of Cuba.

The figured specimens and a collection representing all the species are to be deposited in the United States National Museum.

Family TEXTULARIIDAE

Genus TEXTULARIA Defrance, 1824

TEXTULARIA AGGLUTINANS d'Orbigny

Textularia agglutinans D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 136, pl. 1, figs. 17, 18, 32-34, 1839.

This is a common species of the general West Indian region.

Family VALVULINIDAE

Genus VALVULINA d'Orbigny, 1826

VALVULINA OVIEDOIANA d'Orbigny

Plate 1, fig. 24

Valvulina oviedoiana D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 103, pl. 2, figs. 21, 22, 1839.

This is a characteristic species of shallow water in the West Indies. The figure given shows the aperture with the large valvular tooth.

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA TRICARINATA d'Orbigny

Plate 1, fig. 1

Clavulina tricarinata D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 111, pl. 2, figs. 16-18, 1839.

Typical specimens of this common West Indian species occurred in the collections from Old Providence Island.

CLAVULINA NODOSARIA d'Orbigny

Plate 1, fig. 2

Clavulina nodosaria D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 110, pl. 2, figs. 19, 20, 1839.

This is a much smaller, more delicate species than the preceding, with thin walls.

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA AGGLUTINANS d'Orbigny

Plate 1, fig. 3

Quinqueloculina agglutinans D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 195, pl. 12, figs. 11-13, 1839.

This is a common species in the collections and common in the West Indian region.

QUINQUELOCULINA LAMARCKIANA d'Orbigny

Quinqueloculina lamarckiana D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 189, pl. 11, figs. 14, 15, 1839.

This species has a wide distribution in the general West Indian region.

QUINQUELOCULINA COLLUMNOSA Cushman

Quinqueloculina collumnosa CUSHMAN, Carnegie Inst. Washington, Publ. No. 311, p. 65, pl. 10, fig. 10, 1922.

This species was described from the Tortugas region. Typical specimens occurred in our material.

QUINQUELOCULINA BRADYANA Cushman

Plate 1, figs. 5, 6

Miliolina undosa H. B. BRADY (not *Quinqueloculina undosa* Karrer), Rep. Voy.
   Challenger, Zoology, vol. 9, p. 176, pl. 6, figs. 6-8, 1884.
Quinqueloculina bradyana CUSHMAN, U. S. Nat. Mus. Bull. 71, pt. 6, p. 52,
   pl. 18, fig. 2, 1917.

Specimens occur in our material that seem to belong to this species,
which has been recorded from both the tropical Pacific and Atlantic.

QUINQUELOCULINA cf. Q. KERIMBATICA Heron-Allen and Earland, var. PHILIPPINENSIS Cushman

Plate 2, figs. 2, 3

The figured specimens show a large form that has the periphery
on each chamber strongly reticulate but the sides smooth and un-
ornamented. The variety was described from the Philippines, but
a form similar to the one here figured was recorded from the Dry
Tortugas.

QUINQUELOCULINA POLYGONA d'Orbigny

Quinqueloculina polygona D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
   "Foraminifères," p. 198, pl. 12, figs. 21-23, 1839.

This species has a wide distribution in the West Indian region.

Genus SPIROLOCULINA d'Orbigny, 1826

SPIROLOCULINA GRATELOUPI d'Orbigny

Spiroloculina grateloupi D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 298, 1826.—
   TERQUEM, Mém. Soc. Géol. France, ser. 3, vol. 1, p. 52, pl. 5, figs. 5, 6, 1878.

This species is abundant in the tropical Pacific but has also been
recorded from the West Indian region.

SPIROLOCULINA ORNATA d'Orbigny

Spiroloculina ornata D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
   "Foraminifères," p. 150, pl. 12, figs. 7, 7a, 1839.

This is a rather rare species described by d'Orbigny from shore
sands of Cuba and recorded as rare at several localities in the general
West Indian region.

SPIROLOCULINA ANTILLARUM d'Orbigny

Plate 1, figs. 12-15

Spiroloculina antillarum d'Orbigny, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 166, pl. 9, figs. 3, 4, 1839.

This is a widely distributed species characteristic of shallow tropical waters.

SPIROLOCULINA ARENATA Cushman

Spiroloculina arenata Cushman, Proc. U. S. Nat. Mus., vol. 59, p. 63, pl. 14, fig. 17, 1921.

This species was originally described from the coast of Jamaica but has since been found to be widely distributed in the general region of the West Indies.

Genus ARTICULINA d'Orbigny, 1826

ARTICULINA SAGRA d'Orbigny

Plate 1, fig. 16

Articulina sagra d'Orbigny, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 160, pl. 9, figs. 23-26, 1839.

This is a fairly common species in the material from off Old Providence Island.

ARTICULINA CASSIS (d'Orbigny)

Plate 1, figs. 17-23

Vertebralina cassis d'Orbigny, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 51, pl. 7, figs. 14, 15, 1839.
Articulina cassis Cushman and Hanzawa, Contr. Cushman Lab. Foram. Res., vol. 13, p. 44, 1937.

This species shows a remarkable amount of variation. The usual form has a much broader test, increasing in width even in the completely coiled stage, figure 17. The first uniserial chamber has a flaring lip and a somewhat swollen base, figures 18, 19. Later uniserial chambers may continue of this same type, figures 20, 21, or may become very much broader as in figures 22 and 23. The broad form may be the same as the form named var. *mucronata* by d'Orbigny, but our series seems to show all gradations. The range of variation is even greater than the few figured specimens show. D'Orbigny's records for the species include Cuba, Jamaica, and Martinique, and I have had it also from Puerto Rico and from the Dry Tortugas. The material from Old Providence Island, however, shows a much greater range of variation than from other localities.

Genus TUBINELLA Rhumbler, 1906

TUBINELLA FUNALIS (H. B. Brady)

Articulina funalis H. B. BRADY, Rep. Voy. *Challenger,* Zoology, vol. 9, p. 185, pl. 13, figs. 6-11, 1884.
Tubinella funalis RHUMBLER, Zool. Jahrb., Abt. Syst., vol. 24, p. 26, pl. 2, fig. 3, 1906.—CUSHMAN, Carnegie Inst. Washington, Publ. No. 342, p. 54, pl. 19, figs. 7, 8, 1924.

This is not a common species, and its occurrence at Old Providence Island extends its range in the tropical Atlantic.

Genus HAUERINA d'Orbigny, 1839

HAUERINA BRADYI Cushman

Plate 1, figs. 25-27

Hauerina compressa H. B. BRADY (not *H. compressa* d'Orbigny), Rep. Voy. *Challenger,* Zoology, vol. 9, p. 190, pl. 11, figs. 12, 13, 1884.
Hauerina bradyi CUSHMAN, U. S. Nat. Mus. Bull. 71, pt. 6, p. 62, pl. 23, fig. 2, 1917.

This species was originally described from the Indo-Pacific but has been recorded from numerous localities in the tropical Atlantic.

HAUERINA ORNATISSIMA (Karrer)

Quinqueloculina ornatissima KARRER, Sitz. Akad. Wiss. Wien, vol. 58, p. 151, pl. 3, fig. 2, 1868.
Hauerina ornatissima H. B. BRADY, Rep. Voy. *Challenger,* Zoology, vol. 9, p. 192, pl. 7, figs. 15-22, 1884.

Although a typically Indo-Pacific species, it occurs also in the tropical Atlantic but usually in few numbers.

Genus TRILOCULINA d'Orbigny, 1826

TRILOCULINA TRIGONULA (Lamarck)

Miliolites trigonula LAMARCK, Ann. du Mus., vol. 5, p. 351, No. 3, 1804.
Triloculina trigonula D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 299, No. 1, pl. 16, fig. 5-9, 1826; Modèles, No. 93, 1826.—CUSHMAN, U. S. Nat. Mus. Bull. 71, pt. 6, p. 65, pl. 25, fig. 3, 1917.

This is not a common species in the western Atlantic but is recorded as single specimens from Jamaica and the Dry Tortugas. It may not be the same as Lamarck's species from the Eocene of the Paris Basin.

TRILOCULINA TRICARINATA d'Orbigny

Triloculina tricarinata d'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 299, No. 7, 1826;
Modèles, No. 94, 1826.—H. B. BRADY, Trans. Linn. Soc. London, vol. 24,
p. 446, pl. 48, fig. 3, 1864.

The form from Old Providence Island may be included under this name.

TRILOCULINA OBLONGA (Montagu)

Vermiculum oblongum MONTAGU, Test Brit., p. 522, pl. 14, fig. 9, 1803.
Triloculina oblonga d'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 300, No. 16, 1826;
Modèles, No. 95, 1826; *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "For-
aminifères," p. 175, pl. 10, figs. 3-5, 1839.—CUSHMAN, Proc. U. S. Nat.
Mus., vol. 59, p. 69, pl. 17, figs. 5, 6, 1921.

This is a fairly common species in this material and is widely dis-
tributed in the West Indian region.

TRILOCULINA PLANCIANA d'Orbigny

Triloculina planciana d'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
"Foraminifères," p. 173, pl. 9, figs. 17-19, 1839.—CUSHMAN, Proc. U. S.
Nat. Mus., vol. 59, p. 70, pl. 17, figs. 7, 8, 1921.

This is a common species in the general West Indian region.

TRILOCULINA FICHTELIANA d'Orbigny

Plate 1, figs. 7-9

Triloculina fichteliana d'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
"Foraminifères," p. 171, pl. 9, figs. 8-10, 1839.—CUSHMAN, Proc. U. S. Nat.
Mus., vol. 59, p. 70, pl. 17, figs. 1, 2, 1921.

A widely distributed species in the tropical Atlantic.

TRILOCULINA CARINATA d'Orbigny

Plate 1, figs. 10, 11

Triloculina carinata d'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
"Foraminifères," p. 179, pl. 10, figs. 15-17, 1839.—CUSHMAN, Proc. U. S.
Nat. Mus., vol. 59, p. 71, pl. 17, figs. 9, 10, 1921.

The reticulate ornamentation is very highly developed in this species,
which is common in the general West Indian region.

TRILOCULINA LINNEIANA d'Orbigny

Triloculina linneiana d'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
"Foraminifères," p. 172, pl. 9, figs. 11-13, 1839.

This is a large species widely distributed in tropical waters of both
the Atlantic and Pacific.

Genus PYRGO Defrance, 1924

PYRGO SUBSPHAERICA (d'Orbigny)

Biloculina subsphaerica D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 162, pl. 8, figs. 25-27, 1839.
Pyrgo subsphaerica CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 6, p. 68, pl. 18, figs. 1, 2, 1929.

The most common species of the genus in the West Indian region but never attains a large size.

PYRGO DENTICULATA (H. B. Brady)

Biloculina ringens (LAMARCK) var. *denticulata* H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, p. 143, pl. 3, figs. 4, 5, 1884.
Biloculina denticulata CUSHMAN, U. S. Nat. Mus. Bull. 71, pt. 6, p. 180, pl. 33, fig. 1, 1917; Proc. U. S. Nat. Mus., vol. 59, p. 74, 1921.
Pyrgo denticulata CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 6, p. 69, pl. 18, figs. 3, 4, 1929.

Although typically an Indo-Pacific species it occurs at numerous localities in the tropical Atlantic.

Family OPHTHALMIDIIDAE

Genus CORNUSPIRA Schultze, 1854

CORNUSPIRA INVOLVENS (Reuss)

Operculina involvens REUSS, Denkschr. Akad. Wiss. Wien, vol. 1, p. 370, pl. 45, fig. 20, 1849.
Cornuspira involvens REUSS, Sitz. Akad. Wiss. Wien, vol. 48, 1863, p. 39, pl. 1, fig. 2, 1864.

All the specimens are of small size as is usual in the West Indies.

Family NONIONIDAE

Genus NONION Montfort, 1808

NONION GRATELOUPI (d'Orbigny)

Nonionina grateloupi D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 294, No. 19, 1826; *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 46, pl. 6, figs. 6, 7, 1839.
Nonion grateloupi CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 10, pl. 3, figs. 9-11; pl. 4, figs. 1-4, 1930.

Specimens of this common West Indian species occurred in our material.

Genus ELPHIDIUM Montfort, 1808

ELPHIDIUM POEYANUM (d'Orbigny)

Polystomella poeyana D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 25, 26, 1839.
Elphidium poeyanum CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 25, pl. 10, figs. 4, 5, 1930.

A common species in the West Indian region in warm shallow water, and occurs in our collections.

ELPHIDIUM SAGRUM (d'Orbigny)

Polystomella sagra D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 19, 20, 1839.
Elphidium sagrum CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 24, pl. 9, figs. 5, 6, 1930.

Although usually more rare than the preceding, this species has a wide distribution in the West Indian region both as a living species and in the late Tertiary also.

Family PENEROPLIDAE

Genus PENEROPLIS Montfort, 1808

PENEROPLIS PROTEUS d'Orbigny

Peneroplis protea D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 60, pl. 7, figs. 7-11, 1839.

This is a common species throughout the West Indian region.

PENEROPLIS BRADYI Cushman

Plate 1, fig. 28

Peneroplis planatus CUSHMAN (not Fichtel and Moll), Proc. U. S. Nat. Mus., vol. 59, p. 75, pl. 18, fig. 9, 1921.
Peneroplis bradyi CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 40, pl. 14, figs. 8-10, 1930.

Widely distributed in the West Indian region, this species is only slightly less abundant than the preceding.

Genus MONALYSIDIUM Chapman, 1900

MONALYSIDIUM POLITA Chapman?

This is a rare form in the Atlantic, and its reference to Chapman's Pacific species is open to some question. The same form has been recorded from Puerto Rico and the Dry Tortugas.

Genus ARCHAIAS Montfort, 1808

ARCHAIAS ANGULATUS (Fichtel and Moll)

Nautilus angulatus FICHTEL and MOLL, Test. Micr., p. 112, pl. 21, 1803.
Archaias angulatus CUSHMAN, Cushman Lab. Foram. Res., Special Publ.
    No. 1, p. 218, pl. 31, fig. 9, 1928; U. S. Nat. Mus. Bull. 104, pt. 7, p. 46,
    pl. 16, figs. 1-3; pl. 17, figs. 3-5, 1930.

This is a very abundant species in the shallow water of the western
tropical Atlantic.

Genus AMPHISORUS Ehrenberg, 1838

AMPHISORUS HEMPRICHII Ehrenberg

Plate 2, fig. 1

Amphisorus hemprichii EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838, p. 134,
    pl. 3, fig. 3.—CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 51, pl. 18,
    figs. 5-7, 1930.
Orbitolites duplex W. B. CARPENTER, Rep. Voy. *Challenger,* Zoology, pt. 21,
    p. 25, pl. 3, figs. 8-14; pl. 4, figs. 6-10; pl. 5, figs. 1-13, 1883.

In the general West Indian region this is a very abundant species
of shallow water, frequently attached to the short eel grass, *Posidonia*.

Family ALVEOLINELLIDAE

Genus BORELIS Montfort, 1808

BORELIS PULCHRA (d'Orbigny)

Alveolina pulchra D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
    "Foraminifères," p. 70, pl. 8, figs. 18, 19, 1839.
Borelis pulchra CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 7, p. 55, pl. 15,
    figs. 9, 10, 1930.

Although rare in the West Indian region, it is recorded from several
localities.

Family BULIMINIDAE

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA PUNCTATA d'Orbigny

Virgulina punctata D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba,
    "Foraminifères," p. 139, pl. 1, figs. 35, 36, 1839.

D'Orbigny described this species from the shore sands of the West
Indies. It extends out into deeper water and ranges back to the
Oligocene of this same region.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA COMPACTA Sidebottom

Bolivina robusta H. B. BRADY, var. *compacta* SIDEBOTTOM, Mem. Proc. Manchester Lit. Philos. Soc., vol. 49, No. 5, p. 15, pl. 3, fig. 7, 1905.
Bolivina compacta CUSHMAN, U. S. Nat. Mus. Bull. 71, pt. 2, p. 36, text fig. 58, 1911.

Originally described from the Mediterranean, this species is known from the Pacific at many localities but in the tropical Atlantic has been previously recorded only from the Dry Tortugas.

BOLIVINA PULCHELLA (d'Orbigny)

Sagrina pulchella D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 150, pl. 1, figs. 23, 24, 1839.
Bolivina pulchella CUSHMAN, Carnegie Inst. Washington, Publ. No. 311, p. 25, pl. 1, figs. 8, 9, 1922.

Widely ranging from Bermuda to Rio de Janeiro, Brazil, this is typically a species of the western tropical Atlantic.

BOLIVINA STRIATULA Cushman

Bolivina striatula CUSHMAN, Carnegie Inst. Washington, Publ. No. 311, p. 27, pl. 3, fig. 10, 1922.

Originally described from the Dry Tortugas, this species ranges southward to Brazil and probably occurs in the eastern Atlantic also.

BOLIVINA RHOMBOIDALIS (Millett)

Textularia rhomboidalis MILLETT, Journ. Roy. Micr. Soc., 1899, p. 559, pl. 7, fig. 4.
Bolivina rhomboidalis CUSHMAN, Carnegie Inst. Washington, Publ. No. 311, p. 28, 1922; Cushman Lab. Foram. Res., Special Publ. No. 9, p. 138, pl. 18, fig. 7, 1937.

Millett described this species from the Malay region, and there are numerous records from the tropical Pacific. It has been recorded from the Dry Tortugas and the coast of Cuba. Our specimens seem to be typical.

BOLIVINA TORTUOSA H. B. Brady

Bolivina tortuosa H. B. BRADY, Quart. Journ. Micr. Soc., vol. 21, p. 57, 1881; Rep. Voy. *Challenger,* Zoology, vol. 9, p. 420, pl. 52, figs. 31, 32 (not 33, 34), 1884.

This is a very widely distributed species but seems to hold its characters remarkably well.

Genus LOXOSTOMA Ehrenberg, 1854

LOXOSTOMA MAYORI (Cushman)

Bolivina mayori CUSHMAN, Carnegie Inst. Washington, Publ. No. 311, p. 27,
    pl. 3, figs. 5, 6, 1922.
Loxostomum mayori BERMUDEZ, Mem. Soc. Cubana Hist. Nat., vol. 9, p. 197,
    1935.

Although originally described from the Dry Tortugas, the species
is widely distributed also in the tropical Pacific.

Family ROTALIIDAE

Genus SPIRILLINA Ehrenberg, 1843

SPIRILLINA VIVIPARA Ehrenberg

Spirillina vivipara EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1841, p. 442, pl. 3,
    fig. 41.

A single specimen was found in the collection from 7 to 8 fathoms
inside the reef at Old Providence Island.

Genus PATELLINA Williamson, 1858

PATELLINA CORRUGATA Williamson

Patellina corrugata WILLIAMSON, Rec. Foram. Gt. Britain, p. 46, pl. 3, figs. 86-89,
    1858.

Rare specimens occur in our material.

Genus DISCORBIS Lamarck, 1804

DISCORBIS MIRA Cushman

Plate 2, figs. 4-6

Discorbis turbo H. B. BRADY (and subsequent authors; not d'Orbigny), Rep.
    Voy. *Challenger,* Zoology, vol. 9, p. 642, pl. 87, figs. 8*a-c*, 1884.
Discorbis mira CUSHMAN, Carnegie Inst. Washington, Publ. No. 311, p. 39, pl. 6,
    figs. 10, 11, 1922.

Numerous specimens of this well-characterized species occur in
the Old Providence Island material.

DISCORBIS ORBICULARIS (Terquem)

Rosalina orbicularis TERQUEM, Anim. sur la Plage de Dunkerque, p. 75, pl. 9,
    figs. 4, *a, b,* 1876.
Discorbis orbicularis BERTHELIN, Foram. de Borgneuf et Pornichet, p. 39,
    No. 63, 1878.—CUSHMAN, U. S. Nat. Mus. Bull. 71, pt. 5, p. 16, pl. 11, fig. 1,
    1915.

This species is much less common in our material than the preceding.

DISCORBIS CANDEIANA (d'Orbigny)

Rosalina candeiana D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 97, pl. 4, figs. 2-4, 1839.
Discorbis candeiana CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 8, p. 19, pl. 7, figs. 4*a-c*, 1931.

This is a common and characteristic species of shallow water in the West Indian region.

Genus ROTALIA Lamarck, 1804

ROTALIA ROSEA d'Orbigny

Rotalia rosea D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 272, No. 7, 1826; Modèles, No. 35, 1826.—CUSHMAN, U. S. Nat. Mus. Bull. 104, pt. 8, p. 62, pl. 13, figs. 5*a-c*, 1931.

A characteristic West Indian species notable for its deep reddish color.

Family AMPHISTEGINIDAE

Genus AMPHISTEGINA d'Orbigny, 1826

AMPHISTEGINA LESSONII d'Orbigny

Amphistegina lessonii D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 304, No. 3, pl. 17, figs. 1-4 (*Quoii* in description of plate), 1826; Modèles, No. 98, 1826.

One of the common species of coral-reef conditions in the West Indian region.

Family CYMBALOPORIDAE

Genus TRETOMPHALUS Moebius, 1880

TRETOMPHALUS BULLOIDES (d'Orbigny)

Rosalina bulloides D'ORBIGNY, *in* De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 104, pl. 3, figs. 2-5, 1839.
Tretomphalus bulloides MOEBIUS, Beitr. Meeresfauna Insel Mauritius Seychellen, p. 98, pl. 10, figs. 6-9, 1880.

Although widely distributed in its pelagic stage, this species is evidently attached in the early stages and is characteristic of coral-reef conditions.

Family PLANORBULINIDAE

Genus PLANORBULINA d'Orbigny, 1826

PLANORBULINA MEDITERRANENSIS d'Orbigny

Plate 2, fig. 9

Planorbulina mediterranensis D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 280, No. 2, pl. 14, figs. 4-6, 1826; Modèles, No. 79, 1826.

One of the widely distributed species in shallow water, occurring in great numbers attached to the short eel grass, *Posidonia,* in tropical waters.

PLANORBULINA ACERVALIS H. B. Brady

Plate 2, figs. 7, 8

Planorbulina acervalis H. B. BRADY, Rep. Voy. *Challenger,* Zoology, vol. 9, p. 657, pl. 92, fig. 4, 1884.

Specimens with the periphery distinctly lobed, typical of this species, occur in some numbers in our material.

Genus ACERVULINA Schultze, 1854

ACERVULINA INHAERENS Schultze

Plate 2, fig. 10

Acervulina inhaerens SCHULTZE, Organ. Polythal., p. 68, pl. 6, figs. 13, 14, 1854.

Very large specimens occur in these collections. They have the characteristically coarse porous surface of this species.

EXPLANATION OF PLATES

PLATE 1

All figures × 27

FIG.　1. *Clavulina tricarinata* d'Orbigny.
　　　2. *Clavulina nodosaria* d'Orbigny.
　　　3. *Quinqueloculina agglutinans* d'Orbigny.
　　　4. *Quinqueloculina* sp.
　　5, 6. *Quinqueloculina bradyana* Cushman.
　　7-9. *Triloculina fichteliana* d'Orbigny.
　10, 11. *Triloculina carinata* d'Orbigny.
　12-15. *Spiroloculina antillarum* d'Orbigny.
　　　16. *Articulina sagra* d'Orbigny.
　17-23. *Articulina cassis* (d'Orbigny). Series showing the developmental stages.
　　　24. *Valvulina oviedoiana* d'Orbigny.
　25-27. *Hauerina bradyi* Cushman.
　　　28. *Peneroplis bradyi* Cushman.

PLATE 2

All figures × 27

Fig. 1. *Amphisorus hemprichii* Ehrenberg.
2, 3. *Quinqueloculina* cf. *Q. kerimbatica* Heron-Allen and Earland, var. *philippinensis* Cushman.
4-6. *Discorbis mira* Cushman. 4, 6, dorsal views; 5, ventral view.
7, 8. *Planorbulina acervalis* H. B. Brady.
9. *Planorbulina mediterranensis* d'Orbigny.
10. *Acervulina inhaerens* Schultze.
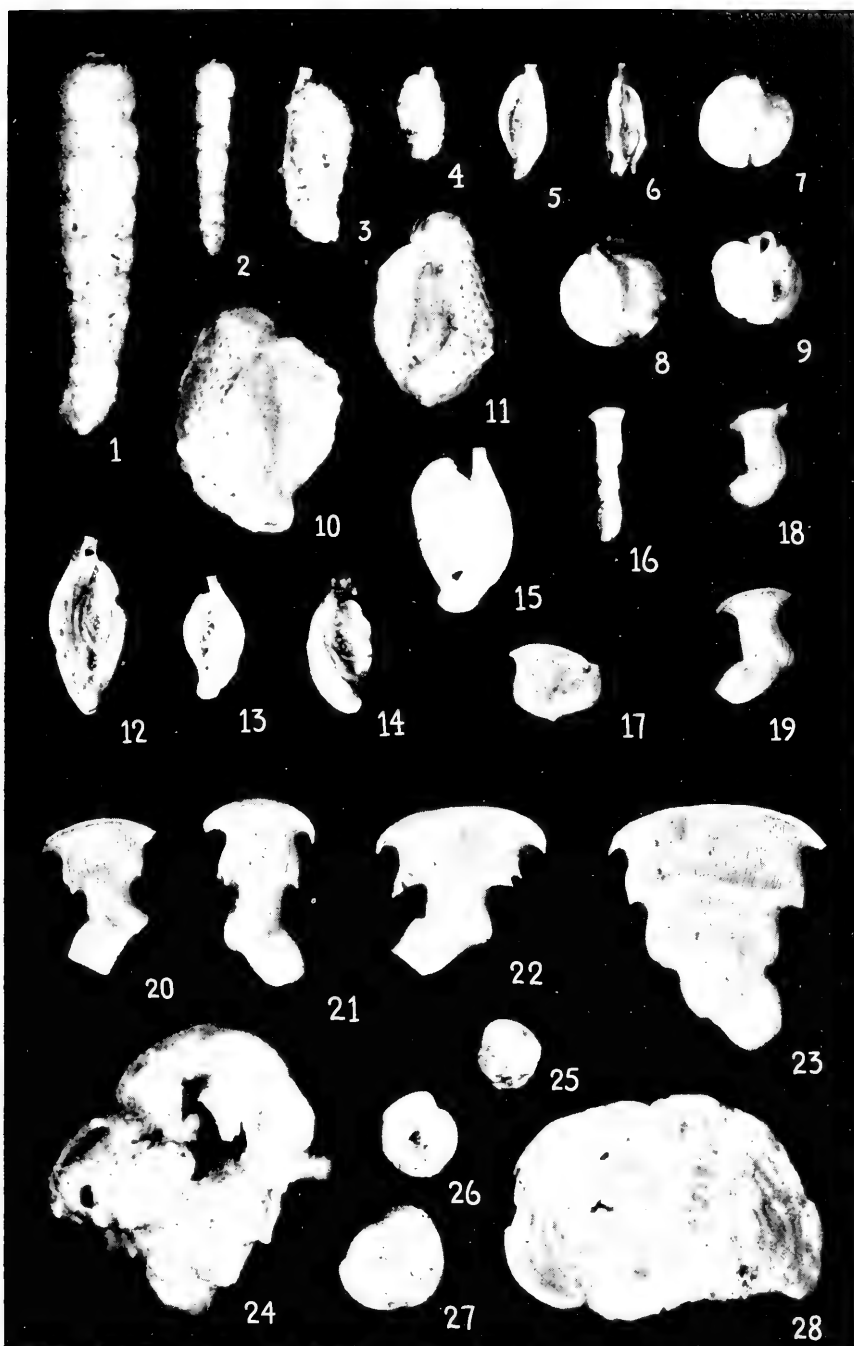
RECENT FORAMINIFERA FROM OLD PROVIDENCE ISLAND

(For explanation see page 13)
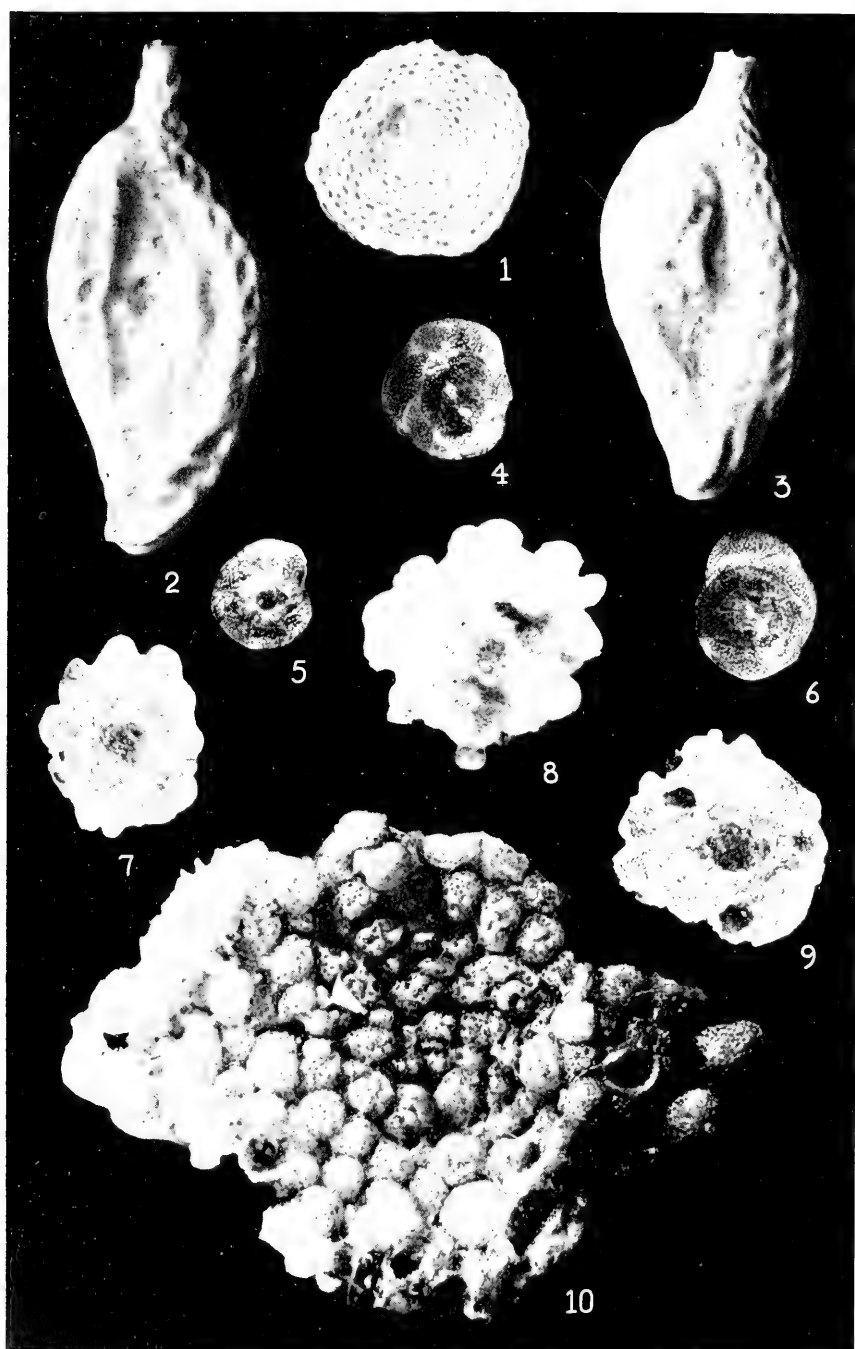
RECENT FORAMINIFERA FROM OLD PROVIDENCE ISLAND

(For explanation see page 14)

COELENTERATES COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

(WITH ONE PLATE)

BY
ELISABETH DEICHMANN
Museum of Comparative Zoology
Cambridge, Mass.

(PUBLICATION 3595)

COELENTERATES COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

(With One Plate)

BY
ELISABETH DEICHMANN
Museum of Comparative Zoology
Cambridge, Mass.

COELENTERATES COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

By ELISABETH DEICHMANN

Museum of Comparative Zoology
Cambridge, Mass.

(WITH ONE PLATE)

The coelenterates collected during the Presidential Cruise to the Galápagos Islands, the Caribbean Sea, and the west coast of Mexico, though few in number, are not without interest. Dr. Waldo L. Schmitt, who was naturalist to the President's party, obtained four species from Old Providence Island (Columbia) off Nicaragua, Caribbean Sea, and five from different localities in the Pacific. Practically nothing has been collected in the western part of the Caribbean Sea. Therefore, the commonest West Indian species represents a new locality record. The same is true of the material from the west coast of Mexico and South America. Almost nothing has been collected from this region since the Agassiz expeditions of the early sixties until the last few years, when the *Velero III, Zaca,* and other expeditions have continued explorations there. Most of the material from these later expeditions is, however, yet to be worked up.

Of the five species collected in the eastern Pacific, two are considered new species; one a new variety, formerly known under another name; one represents the first record since the type was obtained; and one extends the range of the species in question far northward on the west coast of Lower California.

CARIBBEAN COELENTERATES (FROM OLD PROVIDENCE ISLAND)

Erythropodium caribaeorum (Duchassaing and Michelotti)
Briareum asbestinum (Pallas)
Eunicea calyculata (Ellis and Solander)
Pterogorgia bipinnata Verrill

EASTERN PACIFIC COELENTERATES

Muricea (?) *galapagensis,* new species
Elizabeth Bay, Albemarle Island, Galápagos Islands.

Eugorgia rubens Verrill
  San Jose del Cabo, Lower California.
Renilla köllikeri Pfeffer var. *tigrina,* new variety
  San Lucas, Lower California.
Leioptilus undulatus Verrill
  Magdalena Bay, Lower California.
Antipathes galapagensis, new species
  Elizabeth Bay, Albemarle Island, Galápagos Islands.

Family BRIAREIDAE

Genus ERYTHROPODIUM Kölliker

ERYTHROPODIUM CARIBAEORUM (Duchassaing and Michelotti)

Text fig. 1

Xenia caribaeorum DUCHASSAING and MICHELOTTI, 1860, p. 16, pl. 1, figs. 8-11.
Erythropodium caribaeorum KÖLLIKER, 1865, p. 141, pl. 12, figs. 10-11.—
  KÜKENTHAL, 1916, p. 445; 1924, p. 10, text fig. 8.—DEICHMANN, 1936a, p. 77.

Diagnosis.—Colonies encrusting, forming patches several cm. in diameter; thickness of colony up to 5 mm. Polyps small, completely retractile, placed a few millimeters apart. Spicules oblique crosses[1] or stars with clusters of spines; spicules in polyps small (0.03 mm.), larger in the coenenchyma (0.1 mm.). Color superficially dull yellowish or brownish, deeper layer dull brick red. Spicules white, yellow, or red.

Type.—Turin.

Type locality.—St. Thomas, Virgin Islands.

Distribution.—Known from St. Thomas and Jamaica, probably widespread in the West Indies. Now reported from the inner part of the Caribbean Sea, from Old Providence Island.

Depth.—Tide pools.

Specimens examined.—Three fragments of a colony taken in tide pools on the reefs in Old Providence Island.

Remarks.—The species was not represented in the *Blake* material, nor have I seen any material of it in the United States National Museum or the Museum of Comparative Zoology. It is probably much more common than the few records indicate; it is perhaps often mistaken for an encrusting calcareous alga.

---

[1] The name "crosses" is not quite correct. The spicules are obviously derived from a kind of "capstan," a short rod with three short arms at each end. In most cases the arms are unequally developed and the result is a cross with arms of unequal length and shorter arms on the external and internal side. The stars represent twinning or double-twinning of the typical warted "capstans."

Kükenthal, who found it in both St. Thomas and Jamaica and had occasion to compare his material with that of the type, gave a detailed description of it in 1916. The species cannot be mistaken for any other form known from the West Indian waters. The only form which has somewhat similar spicules is *Titanideum suberosum* (Ellis and Solander), but the latter is not known from any locality outside the southern Atlantic States. It forms tall cylindrical or bifurcating stems; the coenenchyma, moreover, contains, besides the characteristic
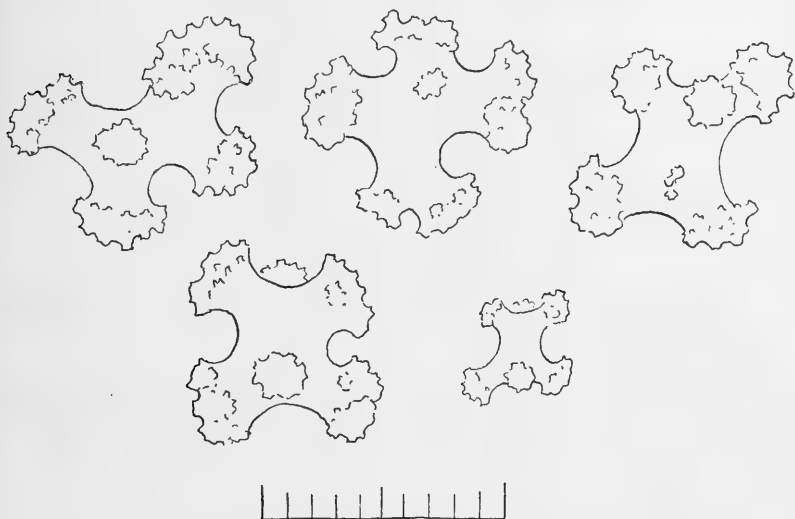
FIG. 1.—*Erythropodium caribaeorum* (Duchassaing and Michelotti). Spicules from coenenchyma and polyp. Scale 1/100 mm.

crosses, also shorter or longer rods. It is, however, possible that future investigations may show that *E. caribaeorum* must be transferred to *Titanideum*.

Genus BRIAREUM Blainville

BRIAREUM ASBESTINUM (Pallas)

Alcyonium asbestinum PALLAS, 1766, p. 344.
Briareum asbestinum KÜKENTHAL, 1924, p. 16, text fig. 15 (complete list of references).—STIASNY, 1935, p. 179, text figs. 1-8; 1937, p. 23, text fig. G.—DEICHMANN, 1936a, p. 79, pl. 5, figs. 1, 2.

Diagnosis.—Colonies forming thicker or thinner encrusting masses, with or without shorter or longer stems, usually 1–2 cm. in diameter, often bifurcate, sometimes developed as fan-shaped thickenings. Polyps distributed over entire colony, completely retractile and lacking spicules in the retractile upper portion. Length of expanded polyp 8–14 mm., in contracted condition 2–3 mm.

Spicules in the outer layer of the coenenchyma shorter or longer pointed rods, sometimes three-armed or branching, with numerous small clusters of spines arranged in more or less distinct transverse rows. Inner layer consisting of more slender rods with a few simple conical spines. No distinct axis, the spicules in the deeper layer surrounded by weakly developed membranes correspond to the horny axis. In the cylindrical stems a number of solenia are present in both the axial part and in the deeper layer of the external tissue. Color of spicules white or purplish, usually white in the external layer and purplish in the deeper layer and near the base of the polyps, but almost white colonies may be found. Shallow-water form.

Type.—Most likely lost.

Type locality.—West Indies.

Distribution.—Widespread in the West Indies.

Specimens examined.—Three fragments from Old Providence Island.

Remarks.—The three fragments differ in color; two are mottled white and purplish, the third is almost white except for a cluster of deep purplish spicules near the base; most striking is the total absence of purplish spicules in the central part of the stem, which makes the colony resemble an *Alcyonium*.

The species has recently been investigated by Stiasny (1935), who found that the polyps are much larger when fully expanded than indicated by previous writers, who had imperfectly preserved colonies before them. Also, Stiasny calls attention to the peculiar manner in which the spines or warts are arranged in transverse rows on the large spicules in the outer layer, a valuable character since it enables one to distinguish this form from species of *Alcyonium* which have spicules of an entirely different type.

As for the moot question whether the present form has short body cavities, as do all other Gorgonians, as Kükenthal maintains, or whether the body cavities are long, as in the Alcyonarians, as Stiasny holds, the present material is not sufficiently well preserved to give any additional information.

Family PLEXAURIDAE

Genus EUNICEA Lamouroux

EUNICEA CALYCULATA (Ellis and Solander)

Gorgonia calyculata Ellis and Solander, 1786, p. 95.
Eunicea calyculata Kükenthal, 1924, p. 120, text fig. 87 (complete list of references).

Diagnosis.—Colonies dichotomously branching, with mostly long branchlets with a diameter of 3–5 mm. Calicles up to 2 mm. long, di-

rected slightly upward; upper lip weakly developed or even missing; in some cases the calicle is almost completely retracted into the coenenchyma.

Spicules an external layer of small white clubs with spines which often are flattened into leaves, a middle layer of long tapering rods with numerous small clusters of warts or spines, color white or purplish or partly white and purplish, an inner layer of short rods with large blunt conical spines. Polyps with a few flat rods in the base of the tentacles and a weakly developed collaret below these. Color of colony purplish overlaid with a white or yellowish layer.

Type.—Probably lost.

Type locality.—West Indies.

Distribution.—Widespread in the West Indies.

Depth.—Shallow water.

Specimens examined.—A small colony from Old Providence Island.

Remarks.—The colony measures 9 cm. in height. It agrees well with Kunze's description (1916, p. 523, pl. 24, fig. 4) except that the branchlets are much shorter, as one must expect them to be in so young a colony. The spicules agree well with those figured by Kunze, text figures H-L (copied by Kükenthal).

Family GORGONIIDAE

Genus PTEROGORGIA Ehrenberg

PTEROGORGIA BIPINNATA Verrill

Pterogorgia bipinnata VERRILL, 1864, p. 31.—DEICHMANN, 1936a, p. 195, pl. 21, figs. 1-16 (complete list of references). (Not *P. bipinnata* Kükenthal, 1924, p. 353 = *P. sparsiramosa* Bielschowsky; not *P. bipinnata* Bielschowsky, 1929, p. 213, pl. 4, fig. 21, text fig. 37 = *P. sparsiramosa* Bielschowsky; not *Gorgonia bipinnata* Hargitt and Rogers, 1902, p. 287, pl. 3, fig. 4, which is possibly a new species.)

Diagnosis.—Colonies branching in one plane with flattened stem and branches of almost equal thickness, and with comparatively short branchlets well spaced. Polyps retractile, arranged along the edges of the flattened branchlets, usually also laterally placed on the stem and branches. Spicules an external layer of scaphoids (0.15–0.18 mm.) with 2–4 conical projections on the convex side and a similar number of clusters of warts on the concave side. Inner layer consisting of long belted rods of about the same length with pointed ends. Polyps without any spicules except a varying number of flattened rods (0.09 mm.) in the base of the tentacles, forming a low operculum. Color purplish to grayish white. Shallow water to about 50 fathoms.

Type.—Museum of Comparative Zoology.

Type locality.—Cumana, Venezuela.

Distribution.—Known from various localities of the northern coast of South America, also from Barbados and Florida.

Depth.—Occurs probably most in deeper water, down to 50 fathoms; therefore, it is comparatively seldom obtained by shore collectors.

Specimens examined.—Two fragments, upper parts of colonies, from Old Providence Island, from shallow water and the bottom of the anchorage.

Remarks.—The fragments are more delicate than the type, the branchlets being extremely soft and flexible, as in a fragment from Florida in the Museum of Comparative Zoology taken during the Pourtalès explorations. The fragment from shallow water is pale purplish and contains numerous purplish spicules in the inner layer. The fragment from the anchorage is dirty white; in life it was brilliant green and was at first taken to be an alga; it lacks the purplish spicules almost completely.

Verrill's species *P. bipinnata* is entirely different from the form which Bielschowsky (and Kükenthal) designate as *"bipinnata."* Their species is now called *P. sparsiramosa* Bielschowsky, as there seems no reason for upholding it as a variety of *bipinnata* since it merely represents a poorly developed form of the supposed *"bipinnata."* The two species are somewhat similar in their external shape, but Bielschowsky's species has long, smooth-backed scaphoids, and the scaphoids and the pointed rods are not distinctly segregated in an inner and outer layer. *P. sparsiramosa* may possibly be identical with Duchassaing and Michelotti's *P. lutescens* from the Antilles, but without the type specimens it seems safer to adopt Bielschowsky's name.

Hargitt and Rogers' *P. bipinnata* (1902, p. 287, pl. 3, fig. 4, overlooked by Deichmann, 1936a) has spicules very similar to those of *P. sparsiramosa,* but it is a more delicate form and the branchlets are united into a regular, wide-meshed network. It probably deserves a new name.

Family MURICEIDAE

Genus MURICEA Lamouroux

MURICEA (?) GALAPAGENSIS, n. sp.

Text figs. 2-4

Diagnosis.—Colony branching almost in one plane with slender stem, branches and branchlets of almost same thickness (2-3 mm.).

Branchlets mostly diverging at wide angle (about 90°) and curved upward. Polyps not crowded, most numerous toward the tips of the branchlets, which are slightly swollen. Upper part of the polyp con-
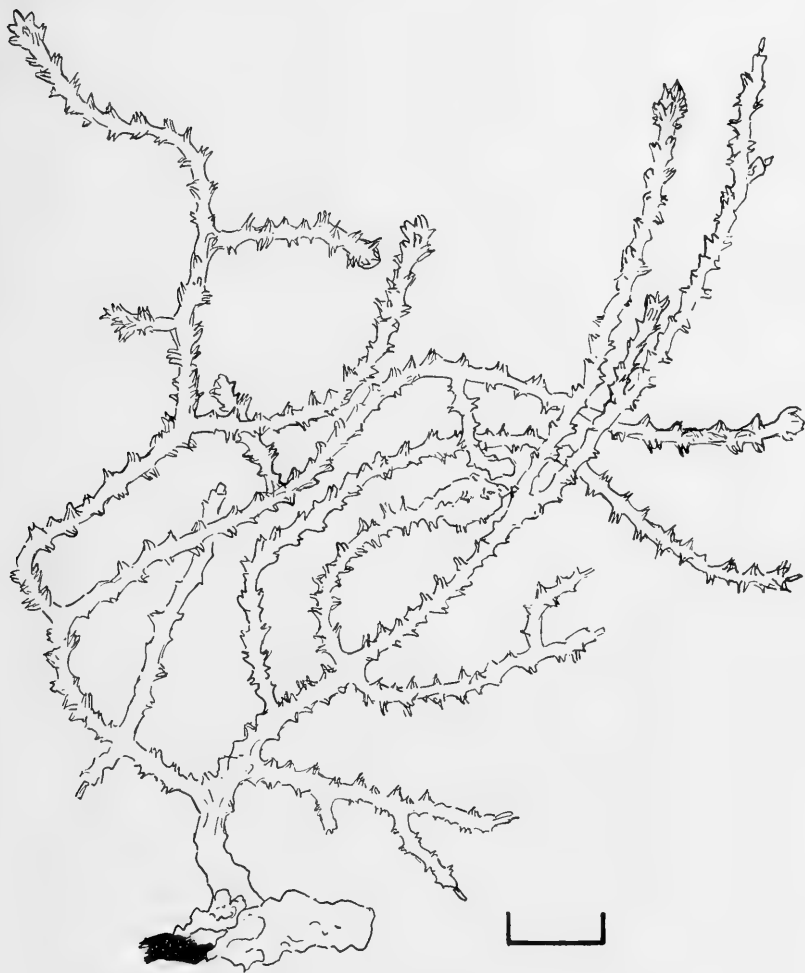
FIG. 2.—*Muricea* (?) *galapagensis*, n. sp. The entire colony, outline. Scale 1 cm.

tracted into the low calicles, which usually are obliquely appressed, with a short lower lip composed of 4–6 projecting spindles and an upper lip, which may be lacking, composed of smaller spindles. Polyps with a few thorny rods in the base of the tentacles forming an operculum, sometimes with a collaret of transversely placed rods. Spicules in coenenchyma: an outer layer of long, often curved spindles (up to

2 mm.), one side of which is covered by minute spines and the other with crowded wartlike projections; an inner layer of shorter rods with few blunt spines. Axis fibrous, brown, paler in the branchlets. Color of type dull orange, outer spicules deep amber, those of the inner layer pale. Another colony is much paler.

Type.—U.S.N.M. No. 43449.

Type locality.—Elizabeth Bay, Albemarle Island, Galápagos Islands, attached to *Antipathes galapagensis,* new species, pulled up with anchor chain, July 26, 1938.

Distribution.—Known from the type locality.

Depth.—About 50 fathoms.

Specimens examined.—The type and a smaller pale colony, also from off the Galápagos (53 fathoms, *Albatross* Sta. 3405) in the Museum of Comparative Zoology.

Remarks.—The type measures about 10 cm. in height. It has a short stem, 1 cm. high, which divides into two branches carrying a few long, well-spaced branchlets which diverge at a wide angle and then usually curve upward; some shorter branchlets diverge almost vertically. The polyps are contracted into low calicles which usually consist of a sheaf of large, pointed spindles that form the lower lip and some smaller spindles that form an indistinct upper lip, which is sometimes lacking or level with the coenenchyma. The coenenchyma is covered by large spindles (1 mm. or more), often curved. Their external side is usually covered by fine spinules, and the inner side is covered by clusters of low warts. Besides, smaller spinules may be present. The inner layer consists of pale, blunt rods or capstans with broad, blunt spines. The polyps have an indistinct operculum of short, spinous rods or spindles; sometimes a collaret is present.

It is with some doubt that the present form is referred to the genus *Muricea,* which is well represented in the tropical western Pacific. The calicles are less numerous and less developed than in most of the species described, but it is possible that the colony represents a poorly developed form. It does not agree with any of the species described by Verrill which I have been able to examine. Aside from the simple mode of branching, it resembles such forms as *Muricea horrida* and *M. fructicosa,* which have fairly scattered calicles and slender stem and branchlets. The spicules are so typical of *Muricea* in their character that it seems natural to keep the species within that genus, or possibly a new genus should be created to take in all the less typical forms.

Studer describes (1894, p. 67) a *Psammogorgia variabilis* from off Colombia, 50 and 100 fathoms. He gives no measurements of the

large spicules, but his description is rather suggestive of the present species, except that the calicles are described as being flattened. His colonies, which were white or terra-cotta brown, are not to be found in the Museum of Comparative Zoology. The specimen from *Albatross* Sta. 3405 was unidentified, and Studer lists no species from that station.

FIG. 3.—*Muricea* (?) *galapagensis,* n. sp. Tip of branchlets, strongly magnified. Scale 1 cm.

Family GORGONIIDAE

Genus EUGORGIA Verrill

EUGORGIA RUBENS Verrill

Eugorgia rubens VERRILL, 1868, p. 411.—KÜKENTHAL, 1924, p. 346.—BIELSCHOW-SKY, 1929, p. 183.

Diagnosis.—Colony branching in one plane with stem and branches of varying thickness according to the age of the colony; branchlets shorter or longer, with a diameter of about 1 mm. and mostly diverging at about 45°. Polyps small, retracted into low conical warts, arranged along the edge of the branchlets, more irregularly placed on

the branches and the stem. Spicules numerous, short, almost ball-shaped bodies with more or less flattened ends, and one pair of belts with warts, sometimes modified into two disks. A few longer rods with pointed ends and two pairs of warted belts are found here and
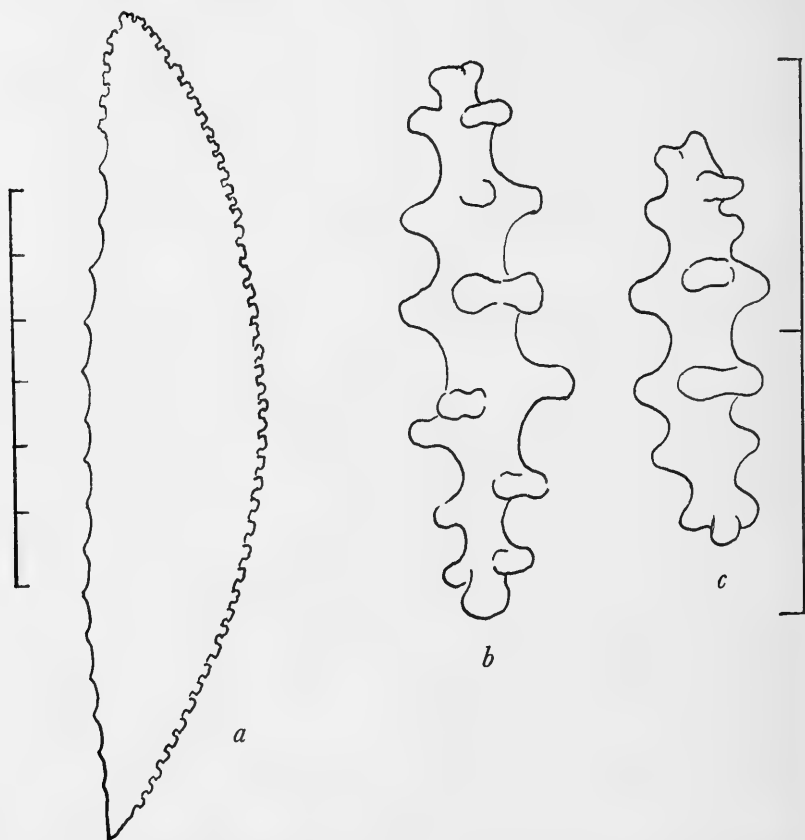
Fig. 4.—*Muricea* (?) *galapagensis*, n. sp. *a*, outline of common spindle-shaped spicule from external layer, medium-sized. *b, c,* spicules from inner layer. Scales 1/10 mm.

there. Polyps apparently without any spicules in the upper part. Color of colony purplish or white.

Type.—Probably lost.

Type locality.—Payta, Peru.

Distribution.—Known from the type locality and from San Jose del Cabo, Lower California.

Specimens examined.—A fragment, the upper part of a white colony, from San Jose del Cabo, Lower California.

Remarks.—The fragment agrees in all respects with a large, almost complete colony in the Museum of Comparative Zoology from the type locality, depth unknown. There is nothing surprising in the great distance between the two localities in which the species has been taken. Most of the forms in the Panama region have a rather wide distribution from north to south. Apparently the present species occurs below tidemark and has therefore rarely been collected.

Family RENILLIDAE

Genus RENILLA Lamarck

RENILLA KÖLLIKERI Pfeffer var. TIGRINA, n. var.

Plate 1, figs. a, b

Renilla amethystina KÜKENTHAL and BROCH, 1911, p. 213, figs. 46, 47.—KÜKEN-
THAL, 1913, p. 263; 1915, p. 23, text figs. 31-34 (complete list of references).
(Not *R. amethystina* Verrill, 1864, p. 29 [*Renilla mülleri* Kölliker].)

Diagnosis.—Renillid with long stalk and almost circular frond with deep incision. Autozooids few, well spaced, with three well-developed marginal teeth and occasionally two more which are feebly developed. Siphonozooids in groups of 3-7, groups distinctly arranged in rows; one or two of the siphonozooids carry a fingerlike tentacle; a few spicules may be present in the center of the groups.

Spicules of the same size as in the typical form, shorter rods (0.25 mm. long) in the stalk and longer (0.40–0.45 mm.) three-flanged needles in the frond. Color of spicules purplish and bright yellow, those of the latter colors being more numerous than in the typical form and occurring around the autozooids and the groups of siphonozooids. Underside of frond and stalk pale purplish except for the tip of the stalk. Autozooids and siphonozooids colorless and without spicules.

Type.—U.S.N.M. No. 43447.

Type locality.—San Lucas, Lower California, 10–15 fathoms.

Distribution.—Known from the type locality and southward (material in other collections). Exact range not known, as it has been more or less confused with other forms.

Depth.—Shallow water to about 15 fathoms.

Specimens examined.—The type and seven paratypes from the same lot.

Remarks.—The material studied consists of large, well-developed colonies, the largest measuring 5 cm. across the frond. In some of the colonies the stalk has been damaged so that it appears as an abnormally small stump.

The typical form is known to reach a much larger size, but colonies of the same size as the present material or smaller have numerous autozooids. Also, the number of teeth around the autozooids is typically 5, sometimes 7 (while the autozooid nearest to the oozooid often has 8 teeth). Furthermore, it is invariably deep purple in color, with few yellow spicules, whereas the variety is pale purplish in color with distinct stripes of yellow radiating from the central midline. Young colonies of the typical form have few autozooids and often a tendency toward striation, but can nevertheless always be distinguished on account of the fewer yellow spicules and the number of teeth around the autozooids.

As far as is known, the areas of distribution for the typical form and the variety are separate. The northern form is known as far south as Ensenada Beach, Lower California, and may be expected to reach Cedros Island, Lower California, which seems to be the southern limit for the Californian shallow-water forms. The variety is known from San Lucas and may possibly reach Magdalena Bay, which seems to be the northern limit for the tropical forms (for example, for *Leioptilus undulatus* Verrill, which often is found in the same localities as this variety of *Renilla*). Nothing, however, is known about the stretch of shore between Magdalena Bay and Cedros Island, which still remains an almost completely unexplored region without any records of either northern or southern forms.

Family PENNATULIDAE

Genus LEIOPTILUS Gray

LEIOPTILUS UNDULATUS Verrill

Plate 1, figs. e, f

Leioptilum undulatum VERRILL, 1865, p. 182.
Leioptilus sinuosus KÜKENTHAL, 1915, p. 95, text fig. 102 (complete list of references). (Not *L. sinuosus* (Gray), 1860, p. 23, pl. 3, fig. 1 [from New Guinea].)
Leioptilus verrilli KÜKENTHAL, 1915, p. 94, text figs. 100-101.
Ptilosarcus undulatus DEICHMANN, 1936b, p. 7.[2]

---

[2] Reexamination of a large number of colonies of *Pennatula fimbriata* (Herklots) in the U. S. National Museum has proved, contrary to the belief of Kükenthal and others, that this species does not properly belong in *Pennatula* and that Gray was correct in placing it in a separate genus, *Leioptilus*. The latter name was unfortunately rejected by me in 1936, as I at that time had not examined any material of *fimbriata*. Nutting's *L. brevicaulis,* in the U. S. National Museum, was found to be a synonym of *L. fimbriata*.

Ptilosarcus gurneyi Boone, 1933, p. 57. (Not *P. gurneyi* (Gray), 1860, p. 23, pl. 3, fig. 2, a northern form.)

Diagnosis.—Leioptilid up to about 15 cm. long, with up to about 26 pairs of leaves, with more than 100 autozooids on the mature leaves. Autozooids with a single tooth on the calicles. Siphonozooids in clusters on the dorsal side; large isolated mesozooids often found between the leaves on the dorsal side, sometimes lacking. Spicules: broad, flat rods in the stalk and scattered in other parts of the colony; long, three-flanged needles in the leaves and in the calicles. Color brownish to purplish, often with white or yellow stem and stalk, sometimes a band of purplish spicules across the stalk. Distal end of autozooid and siphonozooids colorless. Pure white colonies may occur.

Type.—Said to be in the Smithsonian collections, but seems not to be there.

Type locality.—Pinnacati Bay in the northern end of the Gulf of California.

Distribution.—With certainty known from the type locality to Panama, possibly farther south.[3] On the western coast of Lower California reported from Magdalena Bay.

Depth.—Shallow water to about 15 fathoms.

Specimens examined.—One small colony from Magdalena Bay, Lower California, 10-15 fathoms.

Remarks.—The single colony measures 1.1 cm. in length, the smallest colony described from any collection. It was taken July 18, 1938, and undoubtedly represents a colony only a few weeks old. The colony has 7 pairs of leaves with respectively 1, 2, 4, 4, 3, 3, and 2 autozooids in each, beginning with the uppermost ones which are the oldest. Even at this early stage the autozooids have a definite tooth on the edge of the calicles. On the dorsal side a few clusters of siphonozooids (with 2 in each cluster) have appeared; no mesozooids were observed.

The spicules are of the same type as in the adult colonies, but of course much smaller and less clean-cut in form. In the stalk the flat rods or plates measure 0.015 mm. in length; in the leaves the longest needles measure 0.15 mm. In the adult colony the plates in the stalk measure about 0.3 mm. and the three-flanged needles 0.7-0.8 mm., according to Kükenthal's measurements.

---

[3] Boone mentions a fine specimen of *"guerneyi"* from Cocos Island in shallow water (p. 16), but later she mentions Costa Rica as the southernmost locality. One would expect *L. undulatus* to occur as far south as Peru or Ecuador, but comparatively little collecting has been done south of Panama.

The color of the small colony is purplish with white stalk and stem and white autozooids. The spicules are mostly pale purplish in color.

Family ANTIPATHIDAE

Genus ANTIPATHES Pallas

ANTIPATHES GALAPAGENSIS, n. sp.

Plate 1, fig. g

Diagnosis.—Tall, bushy colony, with main stem and main branches of various thicknesses, and long, thin branchlets of different orders well spaced in an irregularly pinnate fashion. Stem and branches with scattered spines; branchlets covered with a fine shagreen of delicate spines with the points distally directed. Polyps scattered irregularly on the stem and branches, on the branchlets arranged in a more or less crowded single row on the upper side. Diameter of the individual polyps about 2 mm.; outline circular or slightly oval; mouth conical, surrounded by 6 tentacles of almost equal size, the lateral ones sometimes being slightly larger.

Type.—U.S.N.M. No. 43443.

Type locality.—Elizabeth Bay, Albemarle Island, Galápagos Islands; pulled up with anchor chain, July 26, 1938.

Range.—Galápagos Islands.

Depth.—About 50 fathoms.

Specimens examined.—The type, consisting of a single large dry colony and a few branchlets in alcohol.

Remarks.—The colony must have measured more than 1 meter in height when alive. The lower part of the stem partly lacks living tissue and is more or less overgrown by various encrusting animals, and on the branches the desiccated polyps are visible as small, pearl-like thickenings on the upper side.

Our species may possibly be found to be identical with the one described by Pourtalès in 1874 (p. 47) as *A. fernandezi.* His description[4] suggests that that is the case. But if that is true, another name must be given to the large specimen with numerous short branchlets which Looser (*Parantipathes? fernandezi* Brook, 1926, p. 272, text fig. 38)[5] redescribed and figured, and referred to Pourtalès' species without having seen Pourtalès' description.

---

[4] "Main stem unknown, branchlets pinnate with alternate and rather long pinnules. Densely hirsute with short spines disposed in longitudinal rows. Spines somewhat compressed and hooked upwards near the tip. Polyps elongated with short tentacles, rather crowded on upper part of pinnules."

[5] "Height 1.70 m. or more, with a conical holdfast 5–7.5 cm. in diameter. The trunk has a diameter of 12.5–18.5 mm. and becomes much branched a few centi-

It is impossible to identify the new species with the form which Verrill (*Antipathes panamensis,* 1868, p. 499) described from 6-8 fathoms off Pearl Islands near Panama.[6] His description suggests Looser's species. Of the latter I have examined a large colony possessed by the National Museum which was collected by Dr. Waldo L. Schmitt in 1926 while at Juan Fernandez under the auspices of the Walter Rathbone Bacon Scholarship of the Smithsonian Institution.

On account of the great uncertainty which prevails in this matter, I have chosen to give the Galápagos specimen a new specific name.

REFERENCES

BIELSCHOWSKY, EVA
   1929. Die Gorgonarien West Indiens. Kap. 6. Die Familie Gorgoniidae, zugleich eine Revision. Zool. Jahrb., suppl. 16, heft 1, pp. 63-234, figs. 1-40, pls. 1-5. (In briefer form, first appeared as a published dissertation: Revision der Familie Gorgoniidae, pp. 1-65, Breslau, 1918.)
BOONE, LEE (PEARL)
   1933. Scientific results of the cruises of the yachts *Eagle* and *Ara,* 1921-28; Coelenterata, Echinodermata, and Mollusca. Bull. Vanderbilt Marine Mus., vol. 4, 217 pp., 133 pls.

---

meters above the base, branches tapering at their extremities to less than 0.5 mm. Branchlets pinnate; pinnae alternate and much shorter than the branchlets, densely hirsute, and covered with short spines in longitudinal rows. Spines somewhat compressed, somewhat curved, the points directed toward the extremity of the pinna. The pinnae are very much longer and more numerous than in *Parantipathes tetrasticha (Parantipathes? tetrasticha* (Pourtalès) Brook, 1889, p. 143).

"Polyps elongated, 1–1.75 mm. long by 0.5–0.75 mm. broad, with short tentacles. The polyps are in a row on the upper part of the pinnae and slender branches."

[6] "Corallum arborescently and densely branched and finely subdivided; the small branches mostly bipinnate and tripinnate. The trunk is quite stout and subdivides in an irregularly arborescent manner into many secondary branches, which divide in the same way. The resulting small branches arise in large numbers along the sides of the larger branches, at distances of .08 to .20 of an inch, many of them remaining small, simple, or sparingly divided branchlets, but mostly subdividing in a pinnate, bipinnate, or even tripinnate manner. The final branchlets are .08 or .10 of an inch apart, small, slender, rather short, rarely more than .15 long without branches, scarcely .02 in diameter. Their surface is densely covered with small, sharp spinules, which are directed obliquely outward and toward the tips of the branchlets.

"Color of the trunk and main branches dull brownish black; branchlets very dark brown.

"Height 13 inches; breadth 10; diameter of trunk .50; of main branches .15 to .25 of an inch.

"Pearl Islands, brought from 6 to 8 fathoms by pearl divers." [Type apparently lost; may possibly be in the Peabody Museum in New Haven.]

BROOK, GEORGE
    1889. Report on the Antipatharia collected by H.M.S. *Challenger* during the years 1873-76. Challenger Rep., Zool., vol. 32, pt. 80, iii + 222 pp., pls. 1-15.

DEICHMANN, ELISABETH
    1936a. The Alcyonaria of the western part of the Atlantic Ocean. Mem. Mus. Comp. Zool., vol. 53, 317 pp., 37 pls.
    1936b. Notes on Pennatulacea and Holothurioidea collected by the first and second Bingham Oceanographic Expeditions 1925-1926. Bull. Bingham Oceanograph. Coll., vol. 5, art. 3, pp. 1-11, text fig. 1.

DUCHASSAING, P., and MICHELOTTI, G.
    1860. Mémoire sur les Corallaires des Antilles. Mem. Acad. Sci. Turin, pp. 279-365 (sep., pp. 1-89), pls. 1-10.

ELLIS, J., and SOLANDER, D.
    1786. The natural history of many curious and uncommon zoophytes collected from various parts of the globe by the late John Ellis. Systematically arranged and described by the late Daniel Solander, xii + 208 pp., 63 pls. London.

GRAY, J. E.
    1860. Revision of the family Pennatulidae, with descriptions of new species in the British Museum. Ann. Mag. Nat. Hist., ser. 3, vol. 5, pp. 20-25, pls. 3-4.

HARGITT, CHARLES W., and ROGERS, CHARLES G.
    1902. The Alcyonaria of Porto Rico. Bull. U. S. Fish Comm., vol. 20, for 1900, pt. 2, pp. 267-287, pls. 1-4, text figs. A-K.

HICKSON, S. J.
    1930. Some alcyonarians from the eastern Pacific Ocean. Proc. Zool. Soc. London, pt. 1, 1930, pp. 209-227, text figs. 1-4, pls. 1-3.

HORN, GEORGE H.
    1860. Descriptions of three new species of Gorgonidae, in the collection of the Academy. Proc. Acad. Nat. Sci., Philadelphia, p. 233.

KÖLLIKER, A. v.
    1865. Icones histiologiacae; oder, Atlas der vergleichenden Gewebelehre, 2. Abt. der feinere Bau der Hoheren Thiere, 1 hefte, die Bindesubstanz der Coelenteraten. Pp. 1-181, pls. 1-19. Leipzig.

KÜKENTHAL, W.
    1913. Über die Alcyonarienfauna Californiens und ihre tiergeographischen Beziehungen. Zool. Jahrb., vol. 35, Abt. Syst., pp. 219-270, pls. 7-8, text figs. A-Z, A^1-K^1.
    1915. Pennatularia. Das Tierreich, 43 Lieferung, xv + 132 pp., 126 text figs.
    1916. Die Gorgonarien West Indiens. Chapter 1, Die Scleraxonien. Zool. Jahrb., suppl. 11, pp. 443-504, pl. 23, text figs. A-Z, A_1.
    1924. Gorgonaria. Das Tierreich, 47 Lieferung, xxviii + 478 pp., 209 text figs.

KÜKENTHAL, W. and BROCH, H.
    1911. Pennatulacea. Wissensch. Ergebnisse Deutsche Tiefsee Exped., etc. (*Valdivia*), 1898-1899, vol. 13, teil 1, heft 2, pp. 113-576, pls. 13-29, 295 text figs. Jena.

KUNZE, G.
    1916. Die Gorgonarian West Indiens, 4, Die Gattung Eunicea Lamouroux. Zool. Jahrb., suppl. 11, heft 1, pp. 505-550, pls. 24-26, 25 text figs.

LOOSER, GUALTERIO

   1926. Un zoofito de Juan Fernández peco concido: Parantipathes? fer-
         nandezi Brook. Rev. Chilena Hist. Nat., Santiago, vol. 30, pp. 269-
         274, fig. 38.

PALLAS, P. S.

   1766. Elenchus Zoophytorum, 432 pp.

POURTALÈS, L. F. DE

   1874. Zoological results of the Hassler Expedition. Deep-sea corals. Illus.
         Cat. Mus. Comp. Zool., No. 8, pt. 1 (Mem. Mus. Comp. Zool.,
         vol. 4), pp. 33-50, pls. 6-9.

   1880. Report on the corals and Antipatharia. Bull. Mus. Comp. Zool., vol. 6,
         No. 4, pp. 95-120, pls. 1-3.

STIASNY, G.

   1935. *Briareum asbestinum* (Pall.), wie ich es sehe. Zool. Anz., vol. 110,
         heft 7/8, pp. 179-190, figs. 1-8.

   1937. Die Gorgonacea der *Siboga*-Expedition. Suppl. 2. Revision der
         Scleraxonia. *Siboga* Exped., Leiden, livr. 130, 138 pp., 8 pls.,
         38 text figs.

STUDER, T.

   1894. Note préliminaire sur les Alcyonaries. Report on the dredging opera-
         tions off the west coast of Central America to the Galapagos, etc.
         Bull. Mus. Comp. Zool., vol. 25, No. 5, pp. 53-69.

VERRILL, A. E.

   1864. List of the polyps and corals sent by the Museum of Comparative
         Zoology to other institutions in exchange, with annotations. Bull.
         Mus. Comp. Zool., vol. 1, pp. 29-60.

   1865. Classification of polyps; and synopsis of the polyps and corals of the
         North Pacific Exploring Expedition, etc. Proc. Essex Inst., vol. 4,
         No. 5, art. 9, pp. 145-152; and art. 12, pp. 181-196, pls. 5-6.

   1868 [1869]. Review of the corals and polyps of the west coast of America.
         Trans. Connecticut Acad. Arts and Sci., vol. 1, No. 6, pp. 377-558
         (reprinted in 1869 with some changes under the general title "Notes
         on Radiata").
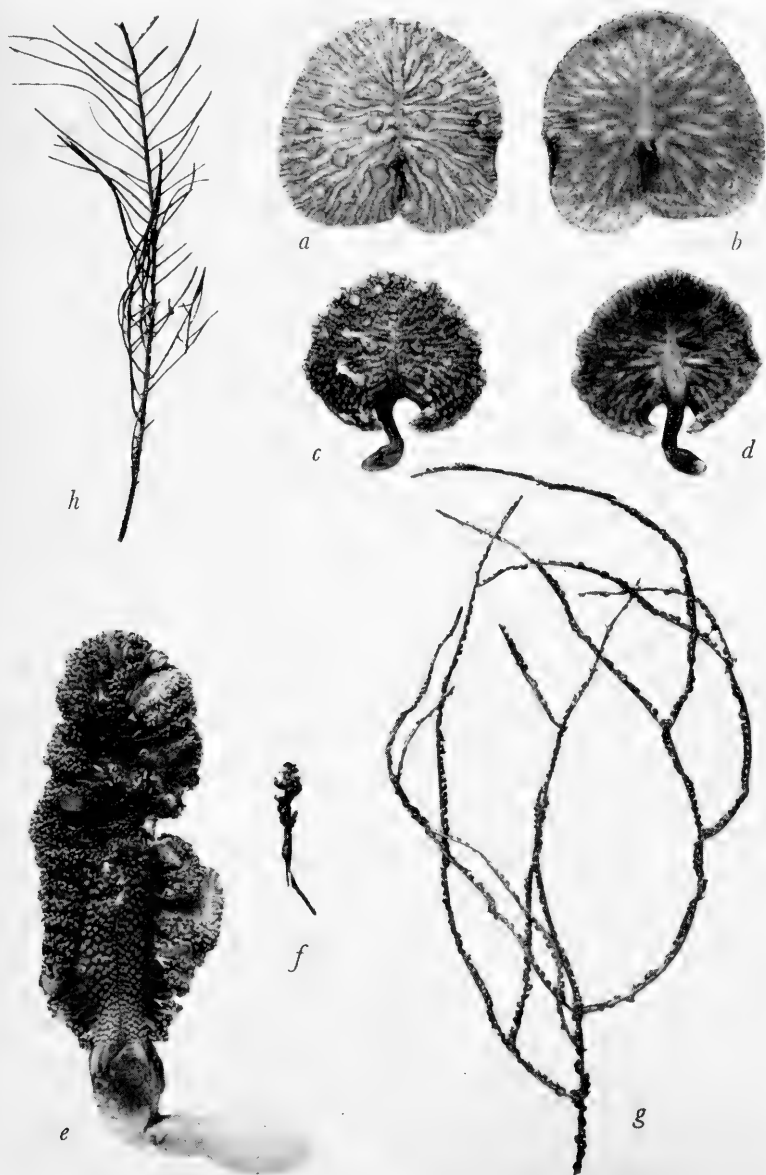
a, *Renilla köllikeri* Pfeffer var. *tigrina*, new variety, dorsal view, ⅔ nat. size. b, *Renilla köllikeri* Pfeffer var. *tigrina*, new variety, ventral view, ⅔ nat. size. c, *Renilla köllikeri* Pfeffer, dorsal view, ⅔ nat. size. d, *Renilla köllikeri* Pfeffer, ventral view, ⅔ nat. size. e, *Leioptilus undulatus* Verrill, ⅔ nat. size. f, *Leioptilus undulatus* Verrill, ×2. g, *Antipathes galapagensis*, new species, ⅔ nat. size. h, *Antipathes panamensis* Verrill, ⅔ nat. size.

A NEW CEPHALOPOD MOLLUSK COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

BY

HELEN C. STUART

Allan Hancock Foundation
The University of Southern California

(PUBLICATION 3596)

A NEW CEPHALOPOD MOLLUSK COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

BY

HELEN C. STUART

Allan Hancock Foundation
The University of Southern California

A NEW CEPHALOPOD MOLLUSK COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

By HELEN C. STUART

Allan Hancock Foundation, The University of Southern California

During President Roosevelt's cruise to the Galápagos Islands in the summer of 1938 aboard the U. S. S. *Houston,* Dr. Waldo L. Schmitt, Naturalist to the expedition, obtained three cephalopods representing a hitherto undescribed species.

The first taken was a small juvenile 17 mm. in length, obtained by means of a dipnet and an electric light lure at 11 o'clock at night off the starboard gangway of the ship while at anchor at South Seymour Island, July 29, 1938 (Station 23a). The other two specimens, a male and a female 623 and 169 mm. in length respectively, were captured among the boulders alongshore by members of the landing party at James Bay, James Island, on the forenoon of July 30, 1938 (Station 25).

The species, of which the large male has been selected as the type, (U.S.N.M. No. 515224) has been named in honor of the President:

OCTOPUS ROOSEVELTI, n. sp.

Description.—Body ovately oblong, width slightly more than one-half the length, thickness about five-sevenths of the width. General body surface rough, dorsally covered with elongated papillae, giving the appearance of a series of longitudinal wrinkles. Along the median longitudinal axis of the body are evidences of elongated tubercles which are prominent in the younger specimen. It is probable that these tubercles have been obliterated in part by pressure against the glass container. Careful scrutiny with a hand lens reveals the quadrilateral pattern of the tubercles on the body proper. Ventral surface of body covered uniformly with regularly spaced papillae forming a rough reticulated surface resembling slightly that of *Octopus cyanea.* Opening of mantle cavity extends to points in line with the ocular aperture, giving this opening approximately 62 percent of the circumference of the head.

Head not particularly prominent, separated from body by a constriction in nuchal region; width slightly less than that of body, length approximately five-sixths of width. Eyes prominent, with small opening on preserved specimen, evidence of a membrane across the entire dorsal half of the eye. Surface of the head covered with irregular-shaped papillae. In the region above the eyes is evidence of several

warted tubercles. Structurally, the eyes become the centers of the
surface pattern. The funnel extends slightly less than one-third of
the distance to the edge of the umbrella. It is conical-shaped, but
blunt at the apex.

Arms long, very stout for about half their length, beyond which
they taper rapidly to attenuated ends. First three basal suckers in a
single row, comparatively small; beginning with the fourth basal
sucker they show a zig-zag position for the entire length of the arm.
Suckers enlarge gradually, reaching maximum size at the edge of
the umbrella; from this point they diminish in size, becoming minute
on the extreme tips of the arms. In the male, at the edge of the um-

1 mm
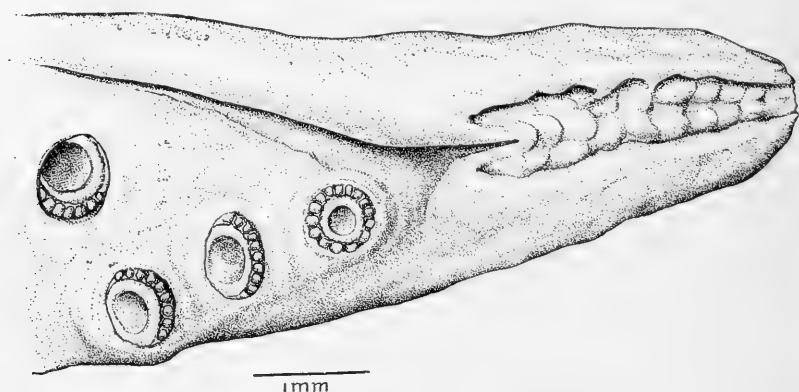
Fig. 1.—*Octopus roosevelti,* hectocotylized portion of third right arm. Drawn
by Anker Petersen.

brella four to six suckers on the lateral arms greatly enlarged, vary-
ing in size from 13 to 19 mm. in diameter. Both dorsal arms and one
ventral arm injured; left dorsal regenerating. Suckers missing in the
vicinity of the edge of the umbrella on the right dorsal and left ventral
arms. There is a gradual increase and decrease in the diameter of
the suckers on all arms. The suckers are deeply cup-shaped; the three
largest are 11 mm. in diameter.

Umbrella well developed, being shortest between the dorsal arms
and longest between the ventral and third pair of arms. Outer surface
of arms and umbrella rough, owing to the presence of papillae. This
is particularly true of the umbrella and the proximal portions of the
arms, where the papillae are elongated. On the outer distal portions
of the arms the papillae become more regular. Smaller papillae cover
the inner surface of the umbrella and arms.

Third right arm shorter than third left arm and bears a compara-
tively minute hectocotylus at its tip (fig. 1). The hectocotylized por-
tion is only 1.7 percent of the length of the entire arm. Seminal

channel pronounced on outer ridge of this arm, beginning at margin of umbrella and ending in the minute, flattened calamus. The ligula narrows to a blunt extremity. Copulatory groove of the ligula shows nine transverse folds made up of irregular nodules.

Color of dorsal surface of body, of outer umbrella, and of outer arms in preserved specimen dull, dusky purple, becoming more intense in

½ mm.
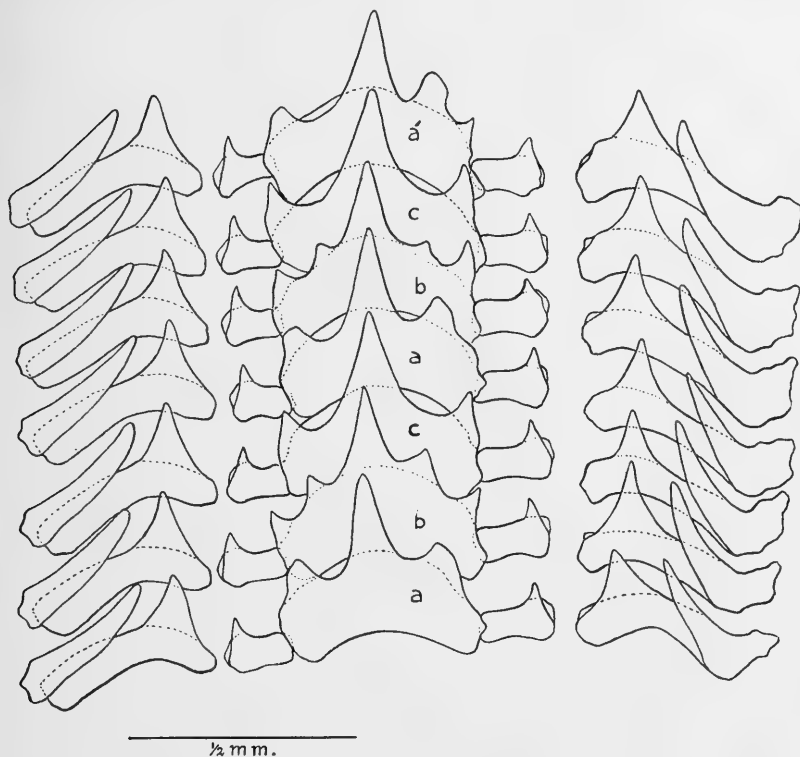
Fig. 2.—*Octopus roosevelti*, rhachidian teeth. Drawn by Anker Petersen.

the folds and wrinkles and on longitudinal papillae and tubercles. When the skin is stretched, a lighter area may be observed between the papillae and the deepest portion of the fold. This lighter area is a stone-gray color. The distribution of light and dark areas gives a reticulated or marbled appearance. The dark color gradually becomes a stone gray on the ventral surface of the body and the inner surface of the umbrella and arms. The stone-gray color is sparsely punctate with purple chromatophores.

The radula contains a multicuspid rhachidian tooth with a strong main cusp, but variations in the minor cusps are noted. The illustration (fig. 2) shows tooth *a* with a blunt cusp on each side of the main cusp. Tooth *b* has two sharply pointed cusps on each side of the

main cusp. Tooth *c,* like tooth *a,* has one cusp on each side of the main cusp, but the minor cusps are sharply pointed. Tooth *a'* is like *a,* but is asymmetrical, having two cusps on one side of the main cusp and only one cusp on the opposite side. These variations of rhachidian tooth are found to be in no particular series or order of sequence. The base of this tooth is slightly wider than the height of the main cusp. The first lateral is twice as wide as it is high, with a sharp cusp on the edge nearest the second lateral. The second lateral has a broad, curved base and a strong, pointed cusp on the portion proximal to the first lateral. The base is almost as wide as that of the rhachidian tooth, but its cusp is only half as high. The third laterals are slender and slightly curved with a heavy base and a sharply pointed cusp. The marginals are indefinite.

Measurements.—Of the only three specimens seen:

	♂ mm.	♀ mm.	Juv. mm.
Total length	623	169	17
Tip of body to dorsal base of umbrella	180	55	11
Length of body (dorsal)	128	25	8
Width of body	70	26	6
Width of neck	50	16	6
Width of head	60	23	6
Length of			
Right dorsal arm	333	117	8
Left dorsal arm	220	115	9
Right second arm	425	141	11
Left second arm	213	142	11
Right third arm	378	143	10
Left third arm	418	139	10
Right ventral arm	442	131	9
Left ventral arm	380	123	10
Length of umbrella between dorsal arms	62	15	1
Length of umbrella between ventral arms	102	17	2
Length of hectocotylus	7	..	..
Diameter of largest sucker	19	4	..
Length of funnel	32	9	1
Width of mantle opening	95	27	8
Depth of body	50	..	5

Remarks.—*O. roosevelti* appears to be most nearly related to *O. bimaculatus* Verrill (1883) and *O. cyanea* Gray (1849). With the latter, as Robson (1929) has shown, *O. horsti* Joubin (1898) and *O. marmoratus* Hoyle (1886) are synonymous. Robson's findings are based upon a detailed examination of the types of these several species.

Of *O. bimaculatus* a wealth of material in all stages of development contained in the collections of the Allan Hancock Foundation has been available for direct comparison. The new species resembles *O. bimacu-*

latus in papillate sculpture, but is a dull, dusky purple with stone-gray reticulations, whereas *O. bimaculatus* is a purplish brown or brownish gray.

Of *O. cyanea,* a male originally determined by Dr. S. Stillman Berry (1914) as *O. marmoratus* Hoyle was lent for study by the Stanford [University] Natural History Museum through the courtesy of Dr. George S. Myers. The female of *O. roosevelti* is ornamented on the dorsal mantle with the same elongated tubercles that form the diamond-shaped quadrilateral that is a common marking on *O. cyanea,* but neither the male nor female of *O. roosevelti* has an ocellus or dark coloring in front of or below the eye on either side. In *O. cyanea,* on the other hand, according to Robson (and Hoyle in his description of *O. marmoratus*), although the ocellus may be concealed in the male, it is plainly to be seen in the female.

Most significant, however, are the differences that one finds in the sequence of the rhachidian or median row of teeth of the several species discussed, together with the structure of the first and third lateral teeth. It is believed that these may best be set forth in tabular form. I myself have examined a number of specimens of *O. bimaculatus* and of course the new species; the observations recorded for *O. cyanea* have been taken from Robson:

O. bimaculatus Verrill	*O. cyanea* Gray	*O. roosevelti* new species
The rhachidian tooth has a low main cusp and a broad base which is nearly twice the height of the main cusp. Occasionally a tooth in the series may have a minute cusp on the outer edge.	The rhachidian has an A_{2-3} seriation.	The rhachidian tooth has a strong main cusp accompanied by either two or four minor cusps. The three-cusp and five-cusp median teeth do not follow in a definite series. The base of the median tooth is slightly wider than the height of the main cusp.
The first lateral has a sharp cusp and an irregular but broad base.	The first lateral has a remarkably high cusp and a narrow base.	The first lateral is twice as wide as it is high, with a sharp cusp on the edge nearest the second lateral.
The second lateral has a strong cusp accompanied by a minor cusp on the portion nearest the first lateral.	The second lateral has neither heel nor ectocone.	The second lateral has a broad curved base and a strong, pointed cusp on the portion proximal to the first lateral.
The third lateral is broad and dull pointed, with a slight curve. The base is decidedly heavy.	The third laterals are thick and moderately curved.	The third lateral is slender and slightly curved with a heavy base.

LITERATURE CITED

BERRY, S. S.

  1912. Review of the Cephalopoda of western North America. Bull. U. S.
        Bur. Fish., vol. 31, pp. 269-336, pls. 32-56, figs. 1-18.

  1914. The Cephalopoda of the Hawaiian Islands. Bull. U. S. Bur. Fish.,
        vol. 32, pp. 257-362, pls. 45-55, figs. 1-40.

D'ORBIGNY, A.

  1835. Voyage dans l'Amérique méridionale, vol. 5, pt. 3, Mollusks, Cephalo-
        pods, pp. 1-64, pls. 1-4.

GRAY, J. E.

  1849. Catalogue of the Mollusca in the collection of the British Museum,
        pt. 1, pp. 8-164, pls. 1-8.

HOYLE, W. E.

  1886. Report of the Cephalopoda collected by H. M. S. *Challenger* during
        the year 1873-76, vol. 16, pt. 44, pp. 1-246, pls. 1-33.

  1907. Cephalopoda: *in* Marine fauna of Zanzibar and East Africa. Proc.
        Zool. Soc. London, pp. 450-461, pl. 20, figs. 128-137.

JOUBIN, M. L.

  1898. Sur quelques céphalopodes du Musée Royal de Leyde et description
        de trois espèces nouvelles. Notes Leyden Mus., vol. 20, pp. 21-28.

ROBSON, G. C.

  1929. A monograph of the recent Cephalopoda based on the collections in
        the British Museum (Natural History), pt. 1, Octopodinae, pp.
        1-236, pls. 1-7, figs. 1-89.

SASAKI, M.

  1929. A monograph of the dibranchiate cephalopods of the Japanese and
        adjacent waters. Journ. Coll. Agric. Hokkaido Imperial Univ.,
        vol. 20, supplementary number, pp. 1-357, pls. 1-30, figs. 1-159.

VERRILL, A. E.

  1883. Description of two species of octopus from California. Bull. Mus.
        Comp. Zool., vol. 11, No. 6, pp. 117-124, pls. 4-6.

ACARINA COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

BY
G. W. WHARTON
Duke University

(PUBLICATION 3597)

ACARINA COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

BY
G. W. WHARTON
Duke University

ACARINA COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

By G. W. WHARTON

Duke University

The mites which are to be discussed in this paper were collected by Dr. Waldo L. Schmitt in the debris from some boobies' (*Sula leucogaster nesiotes* Heller and Snodgrass) nests on Clipperton Island, July 21, 1938. As might be expected from such an environment, there were parasitic as well as free-living species present in the collection. The writer wishes to thank Dr. Schmitt for the opportunity to study these interesting specimens, J. F. Mangrum, Lincoln Memorial University, for mounting a good number of the specimens, and Dr. H. E. Ewing for critically inspecting the material with the author.

Small animals, such as mites, which have very limited powers of locomotion, present an interesting problem when found on oceanic islands. This problem is their origin. It is probable that the parasitic species found were transported to the nesting sites of the birds by the boobies themselves. As for the free-living species, the above-mentioned explanation or other means such as man, wind, or floating logs are equally probable.

The species found were: *Eulaelaps roosevelti,* n. sp. (named in honor of President Franklin D. Roosevelt who made the expedition possible), *Atricholaelaps clippertonensis,* n. sp., *Asca quinquesetosa,* n. sp., two to four unidentified species of the genus *Uropoda, Scheloribates indica* Oudemans, 1917, and *Scheloribates fimbriatus calcaratus* Jacot, 1934.

Species of the genus *Eulaelaps* are usually parasitic upon small mammals and are often found in their nests. However, Pearse (1930) found one parasitic on a crab in Japan. Recently, Fonseca (1935) reported a new species of the genus, *Eulaelaps vitzthumi,* from Brazil. *Eulaelaps* is also known from Europe, and hence it may be considered as having a world-wide distribution, as do a great number of acarinid genera. Concerning the geographic origin of *E. roosevelti,* nothing can be said; as for its mode of transportation to Clipperton, it has most likely come with its host, which is probably the booby *Sula leucogaster nesiotes* Heller and Snodgrass, with which it was found associated.

Many species of the genus *Atricholaelaps* are found as parasites of rodents in North and South America. It is probable that *A. clipper-tonensis* is derived from the American continent. Its method of transportation to the islands is probably the same as that employed by *E. roosevelti.*

The Uropodids and *Asca quinquesetosa* are not parasitic nor can any statement be made as to their probable origin. The other two non-parasitic species, *Scheloribates indica* and *Scheloribates fimbriatus calcaratus,* were found by Jacot (1934) on the Hawaiian Islands. Since both these mites originally came from Asia, it is probable that those on Clipperton were derived from Hawaii.

DESCRIPTION OF NEW SPECIES

Family ASCAIDAE

ASCA QUINQUESETOSA, n. sp.

Female (fig. 1).—Length from posterior margin to tip of hypostome, 0.44 mm. Width, maximum, 0.25 mm. Chelicerae chelate with a single hair on immovable finger opposite tooth, movable and immovable finger each with a single tooth and toothlike hooked ends, hand 0.22 mm. long. Palps, of usual form, 0.11 mm. long from base of trochanter to tip, longest segment palp trochanter, single bristle on ventral side of immovable palp coxa. Epistome two-pronged, one-half length of hypostome. Hypostome 0.07 mm. long with three pairs of setae, extends to anterior level of palp trochanter. Tritosternum, barbed, 0.05 mm. long. Legs stout, none longer than body, each with caroncle and claws, leg II stoutest, legs I and IV longest and subequal, leg III shortest, setae on legs fine below, larger above. Sternal plate extends from behind coxae I to middle of coxae III, 0.11 mm. long, 0.07 mm. maximum width; first pair of sternal hairs in anterior lateral region of plate, first sternal pores concave posteriorly just below first pair of sternal hairs; second pair of sternal hairs opposite middle of coxae II, second pair of sternal pores lateral between coxae II and III; last pair of sternal hairs opposite middle of coxae III, last sternal pores at posterior lateral margin of sternal plate. Metasternal plates lightly chitinized but clearly defined, triangular, base 0.03 mm., altitude 0.01 mm., metasternal hair in center of each plate. Genital opening, transverse slit between metasternal plates, concave posteriorly, 0.04 mm. wide. Genital plate, a regular trapezoid with anterior and posterior margins parallel, anterior margin 0.04 mm. behind the sternal plate and 0.04 mm. wide, posterior margin

0.06 mm. wide, 0.04 mm. long; genital hairs lateral, 0.01 mm. anterior to posterior margin of genital plate. Ventral and anal plates fused, sculptured, irregularly oval, truncate posteriorly, less than
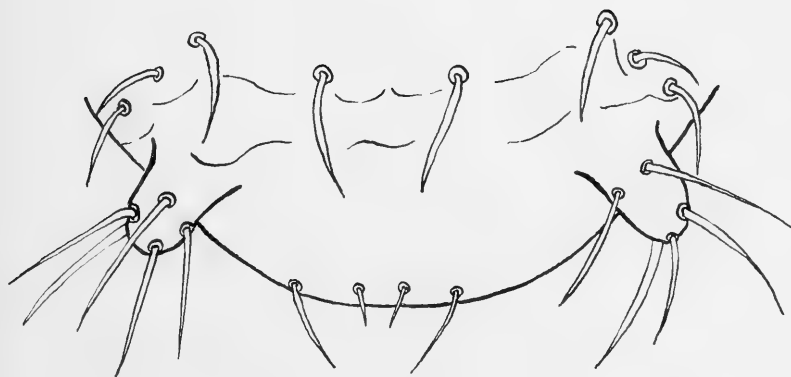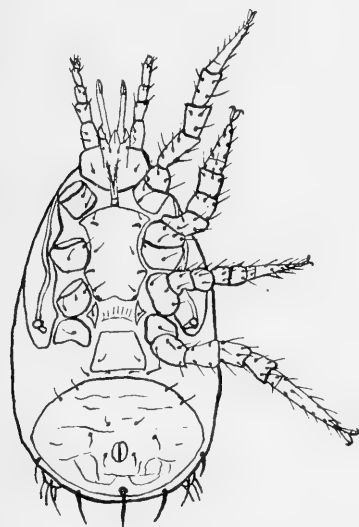
FIG. 1.—*Asca quinquesetosa*, n. sp. ♀. Ventral view. Chelicera. Posterior dorsum.

0.01 mm. behind genital plate, 0.14 mm. long, 0.20 mm. wide; two pairs of hairs on anterior lateral margin, three pairs of hairs anterior and lateral to the anal opening, one stout hair at the median posterior margin; anal opening 0.04 mm. from posterior margin of ventro-

anal plate, 0.20 mm. long, 0.15 mm. wide. Two pairs of hairs on the body in a straight line between the genital and ventro-anal plates. Metapodal plates absent. Parapodal plates distinct. Stigma opposite middle of coxae IV; peritremata extend anteriorly beyond coxae I, sinuate. Dorsal plate divided in two, joint between coxae III and IV; sculptured; sparsely clothed with setae three times as long as those on venter; dorsal plate more heavily chitinized than ventral plate, pair of tubercles, each 0.12 mm. long, on posterior lateral region of dorsum, each tubercle with five setae.

Male.—Unknown.

Type specimens.—U.S.N.M. No. 1374.

Type locality.—Clipperton Island.

Diagnosis.—*A. quinquesetosa* can be recognized by the five setae on the posterior tubercles.

Family LAELAPTIDAE

EULAELAPS ROOSEVELTI, n. sp.

Female (fig. 2).—Length from posterior margin to tip of hypostome 0.75 mm. Width, maximum, 0.40 mm. Chelicerae with a single hair on fixed finger, fixed finger with two teeth and recurved end, movable finger with two teeth and hooked end shorter than fixed finger, a corona of five chitinous spines at base of movable digit, hand 0.07 mm. long. Palps of usual form, 0.18 mm. from base of trochanter to tip, longest segment palp trochanter, single bristle on ventral side of immovable palp coxa. Epistome short, each lateral anterior margin forms a small sharp prong. Hypostome 0.16 mm. long, with three pairs of setae, extends to level of middle of palp femur. Tritosternum, barbed, 0.11 mm. long. Legs stout, none longer than body, leg I longest, leg IV next, leg III next, leg II shortest and stoutest with a well-developed subapical accessory claw, all legs with caroncle and claws, and numerous setae. Sternal plate extends from between coxae I to between the middle of coxae IV, sculptured anterior to middle of coxae III, lateral length of 0.21 mm., median length 0.18 mm., maximum width 0.19 mm.; first pair of sternal setae at the anterior margin 0.05 mm. apart, first sternal pores concave anteriorly just below first hairs; second sternal hairs just behind the middle level of coxae II, second pair of sternal pores not visible; last pair of sternal hairs opposite middle of coxae III, last pair of sternal pores oval, between coxae III and IV. Metasternal plates discrete, triangular base 0.3 mm., altitude 0.2 mm., between coxae III and IV, meta-

sternal hair in center of metasternal plate. Genital and ventral plates fused, 0.22 mm. long and 0.22 mm. wide at its maximum width, convex anteriorly, concave posteriorly, one pair of hairs just behind coxae IV, a second lateral pair 0.06 mm. anterior to the posterior margin of the plate, anterior rim of plate crenate. Genital opening a transverse slit
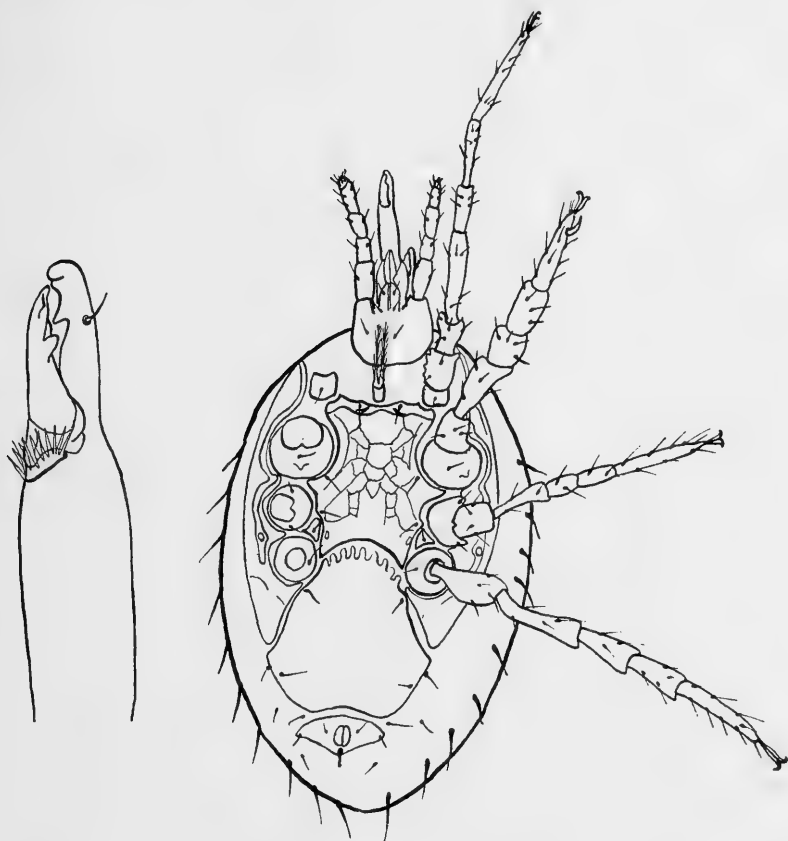
FIG. 2.—*Eulaelaps roosevelti*, n. sp. ♀. Ventral view. Chelicera.

separating sternal and genito-ventral plates. Anal plate triangular, broader than long, width 0.11 mm., length 0.5 mm.; one pair of setae in the lateral margins, one pair lateral to the anal opening, and one median hair posterior to anal opening, anus oval, 0.03 mm. long and 0.02 mm. wide. Metapodal plates large, triangular, fused to parapodal plates. Parapodal plates distinct, well chitinized. Stigmata circular, between coxae III and IV. Peritremata sinuous, extend 0.03 mm.

behind stigmata and anteriorly in front of coxae I. Dorsal shield
not as heavily chitinized as ventral shields, with long, thin, sparse
setae. Four pairs of hairs on venter behind coxae IV not on shields,
ten pairs of marginal setae not on shields.

Male.—Unknown.

Type specimens.—U.S.N.M. No. 1375.

Type locality.—Clipperton Island.

Diagnosis.—*E. roosevelti* can be readily distinguished from the
other members of the genus *Eulaelaps* because the metapodal and
parapodal plates are fused in *E. roosevelti* and not in the others. Per-
haps this character might be used as the basis for a new genus, but
this fusion is anticipated by the close proximity of the metapodal and
parapodal plates in *E. stabularis.*

ATRICHOLAELAPS CLIPPERTONENSIS, n. sp.

Female (fig. 3).—Length from posterior margin to tip of hypo-
stome 0.73 mm. Maximum width 0.36 mm. Chelicerae with a corona
of delicate chitinous spines at the base of the movable digit, movable
digit with three teeth and hooked end, fixed finger with six teeth
and hooked end longer than movable finger, a single seta at the tip
of the fixed digit, hand 0.07 mm. long. Palps of usual form, longest
segment femur, palp 0.15 mm. from base of trochanter to tip. Epi-
stome small, straight. Hypostome 0.10 mm. long, with four pairs of
setae. Tritosternum 0.11 mm. long, barbed. Legs I and IV subequal
and just shorter than body, leg III shortest, leg II stoutest, all with
numerous setae, caroncles and claws at tip of each tarsus. Sternal
plate begins between coxae I, ends between coxae III, length 0.17 mm.,
maximum width 0.12 mm., anterior margin indented to fit about base
of tritosternum, posterior margin faint, fused at side with meta-
sternal shields; first sternal hairs in middle of anterior lateral margin,
first sternal pores just below first hairs; second pair of sternal setae
opposite middle of coxae II, second pair of sternal pores just posterior
to second pair of hairs; third pair of hairs opposite coxae III, third
pair of pores not seen. Metasternal plates fused to sternal 0.05 mm.
long and 0.02 mm. wide, between coxae III and IV; metasternal hairs
present. Genital and ventral shields fused to form a narrow genito-
ventral shield, 0.14 mm. long, 0.08 mm. wide, rounded at posterior
margin; genital pair of setae on anterior corners of shield, no other
setae present. Genital opening a transverse slit between sternal and

genito-ventral shields. Anal shield triangular with rounded corners, length 0.09 mm., width 0.07 mm., paired setae lateral to anal opening, median hair at posterior margin; anal opening oval, length 0.03 mm., width 0.02 mm. Six pairs of setae on venter behind coxae IV, marginal setae like those on dorsal plate spaced about 0.04 mm. apart.
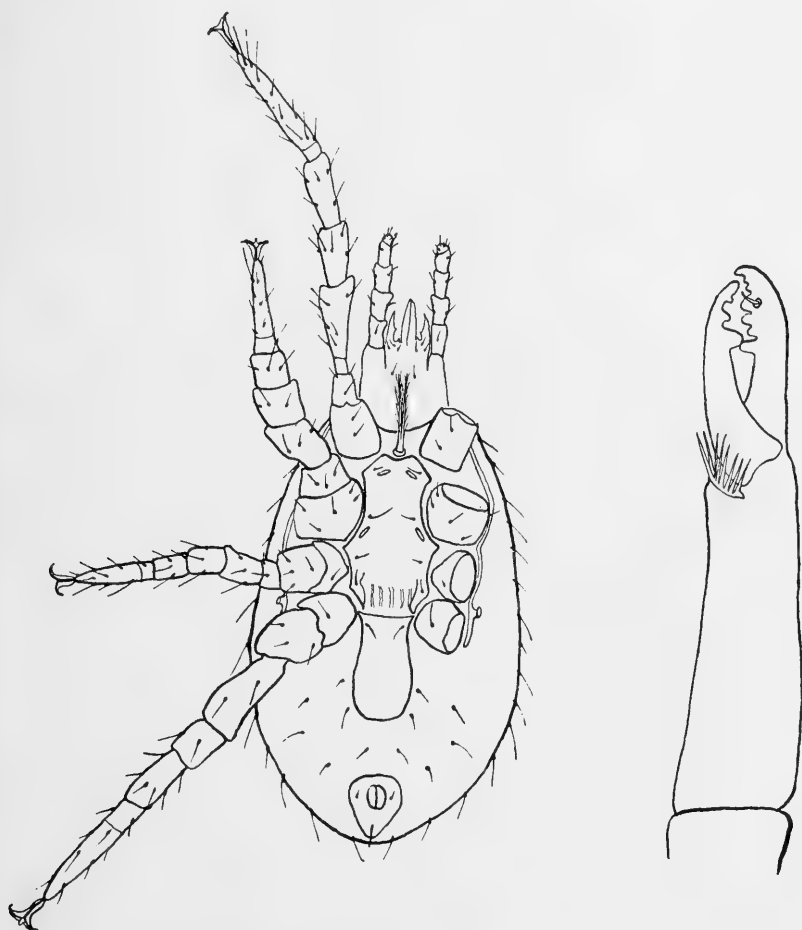
FIG. 3.—*Atricholaelaps clippertonensis,* n. sp. ♀. Ventral view. Chelicera.

Dorsal plate clothed entirely by several large lance-shaped setae. Metapodal plates absent. Parapodal plates absent. Stigmata between coxae III and IV. Peritremata extend posteriorly for 0.05 mm. and anteriorly in front of coxae I.

Male (fig. 4).—Length 0.47 mm., width 0.24 mm. Chelicerae with long ribbonlike spermatophore bearers, arising from movable digit,

hand 0.06 mm. long, ribbon 0.13 mm. long. Leg I stoutest. Ventral plates fused, genital opening on anterior margin, circular, 0.02 mm. in diameter. Hairs on dorsum same as in female.

Type specimens.—U.S.N.M. No. 1376.

Type locality.—Clipperton Island.

Diagnosis.—The crown of delicate spines at the base of the movable digit of the chelicerae of the female will distinguish *A. clippertonensis* from other species of the genus *Atricholaelaps.*
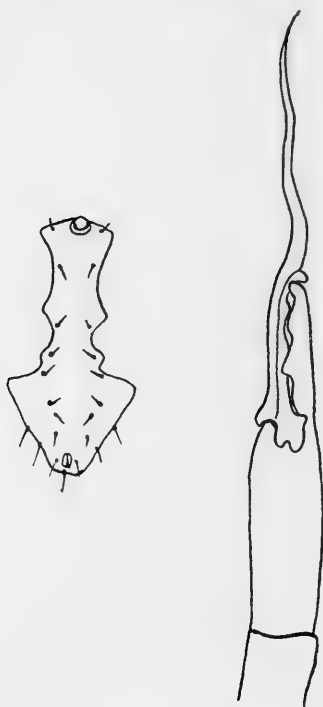
FIG. 4.—*Atricholaelaps clippertonensis*, n. sp. ♂. Ventral plates. Chelicera.

REFERENCES

Ewing, H. E.
    1929. A manual of external parasites. xiv 225 pp. Baltimore.
da Fonseca, F.
    1935. Notas de Acareologia *Eulaelaps vitzthumi* sp. n. Mem. Inst. Butantan S. Paulo, vol. 9, pp. 59-64.
Jacot, A. P.
    1934. Some Hawaiian Oribatoidea (Acarina). Bull. Bishop Mus. Honolulu, vol. 121, pp. 1-99.
Pearse, A. S.
    1930. Parasites of Japanese Crustacea. Annot. Zool. Jap., vol. 13, pp. 1-8.

EUPHAUSIACEA AND MYSIDACEA COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

BY

W. M. TATTERSALL

University College
Cardiff, Wales

(PUBLICATION 3598)

EUPHAUSIACEA AND MYSIDACEA COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

BY
W. M. TATTERSALL
University College
Cardiff, Wales

.

EUPHAUSIACEA AND MYSIDACEA COLLECTED ON THE PRESIDENTIAL CRUISE OF 1938

By W. M. TATTERSALL

University College, Cardiff, Wales

The collection submitted to me for examination is a small one, including only three species. One of these is a new species of the genus *Siriella* which I take pleasure in associating with the President of the United States as a mark of appreciation of his interest in marine biological research. There is also a new species of the genus *Neomysis,* but, since the material includes only female specimens, it seems best to await further material before completing the description. The third species is an already known species of Euphausian. I wish to express my thanks to Dr. Waldo L. Schmitt for kindly allowing me to examine and report on this collection.

Order EUPHAUSIACEA

Genus NYCTIPHANES G. O. Sars

NYCTIPHANES SIMPLEX H. J. Hansen

N. simplex HANSEN, 1911, 1912, and 1915.
N. simplex ESTERLEY, 1914.

Occurrence.—Station 17, July 25, 1938, at anchorage of Tagus Cove, Albemarle Islands, surface, electric light, 11 p.m., two males.

Distribution.—Hansen has recorded this species from several localities in the eastern Pacific, including some from the Galápagos Islands. Esterley's specimens were caught off the coasts of California. According to Hansen the species is known only from the eastern Pacific between latitude 36° N. and 6° S.

Order MYSIDACEA
Suborder MYSIDA
Family MYSIDAE
Subfamily SIRIELLINAE
Genus **SIRIELLA** Dana
SIRIELLA ROOSEVELTI, n. sp.
Figs. 1-2

Occurrence.—Station 17, July 25, 1938, at anchorage off Tagus Cove, Albemarle Islands, surface, electric light, 11 p.m., one male. Station 22, July 27, 1938, at anchorage off Gardner Bay, Hood Island, surface, electric light, 11 p.m., 18 females, 8 males, and 47 half-grown specimens. Types, U.S.N.M. No. 79279. Station 23a, July 7, 1938, at anchorage South Seymour Island, surface, electric light, 11 p.m., 1 male, 5 females, and 35 immature specimens. (Acc. No. 148787.)

Description.—A *Siriella* belonging to group II (Hansen, 1910) in which the apex of the telson is armed with three small spines in the center and a single pair of long lateral spines; the exopod of the uropods longer than the endopods with more than half of the margin of the proximal joint furnished with spines; spines along the distal third of the lateral margins of the telson irregular, with smaller spines in series between the larger spines; *both* rami of *both* the third and fourth pairs of pleopods of the male with modified distal setae; pseudobranchial rami on the second to the fourth pleopods of the male spirally twisted; distal joint of the outer uropod less than twice as long as broad; antennal scale without spines on the outer margin.

Carapace similar in both sexes, only slightly produced into a short triangular rostral plate with a pointed apex which extends scarcely beyond the base of the eyestalks; eyes of moderate size, pigment black.

Antennal scale (fig. 1*a*) extending as far forward as the distal end of the antennular peduncle, four times as long as broad, terminal lobe rather broader than long, extending beyond the distal spine of the outer margin, apex of the lobe marked off by a distinct suture.

Sixth joint of the endopods of the third to the eighth thoracic limbs (fig. 1*b*) divided by a transverse suture into two parts, the proximal part rather less than one-quarter of the whole joint.

Both rami of the third pleopods (fig. 2*a*) of the male with two modified setae at the distal end, the outer seta is stout and smooth, the inner seta slightly more slender than the outer and plumose at the distal end.

The endopod of the fourth pleopod of the male (fig. 2b) has two strong, smooth, modified setae at the apex set at a widely divergent angle which is constant and characteristic; the penultimate joint has a long stout and smooth seta on the outer angle; the exopod has two
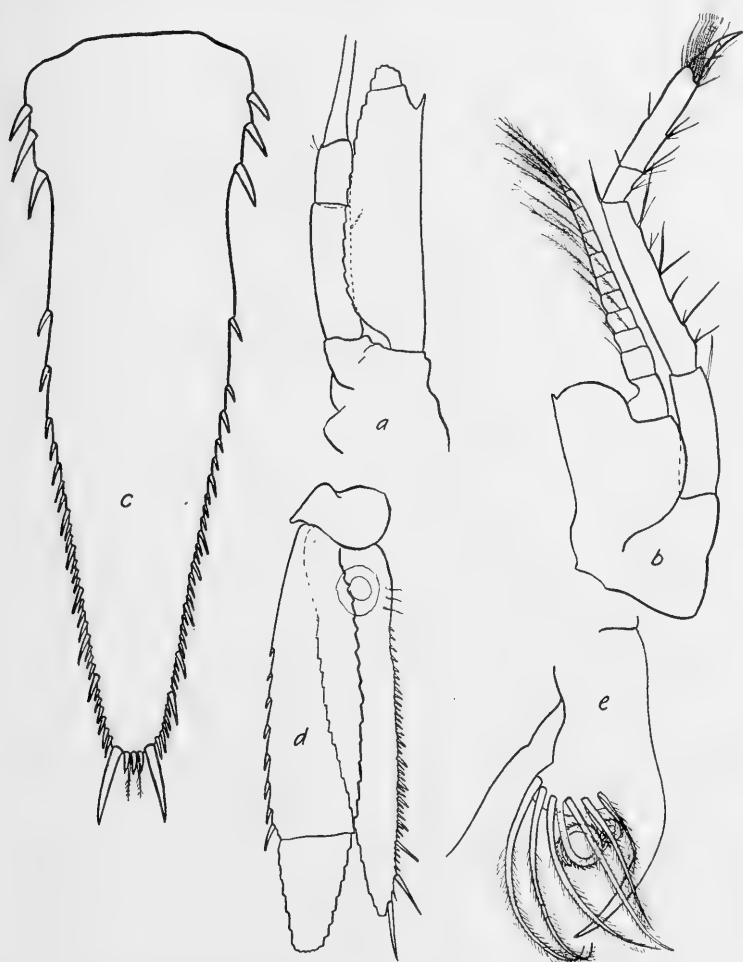
Fig. 1.—*Siriella roosevelti*, n. sp. *a*, antennal scale and peduncle, ✕ 45. *b*, third thoracic limb, ✕ 45. *c*, telson, ✕ 83. *d*, uropods, ✕ 45. *e*, copulatory appendage of the eighth thoracic limb of the male, ✕ 80.

modified setae at the apex, one of which is very long and characteristically bent about one-third of the distance from the base, the other short, less than half the length of the other seta, and smooth.

Endopod of the uropods (fig. 1d) distinctly shorter than the exopod, with a row of spines extending from the statocyst to the distal

end, rather irregular and arranged in groups distally; among them near the distal end are three or four specially long, strong, and prominent spines.

Exopod of the uropods (fig. 1*d*) with the proximal joint three times as long as the distal, with eight or nine spines somewhat widely
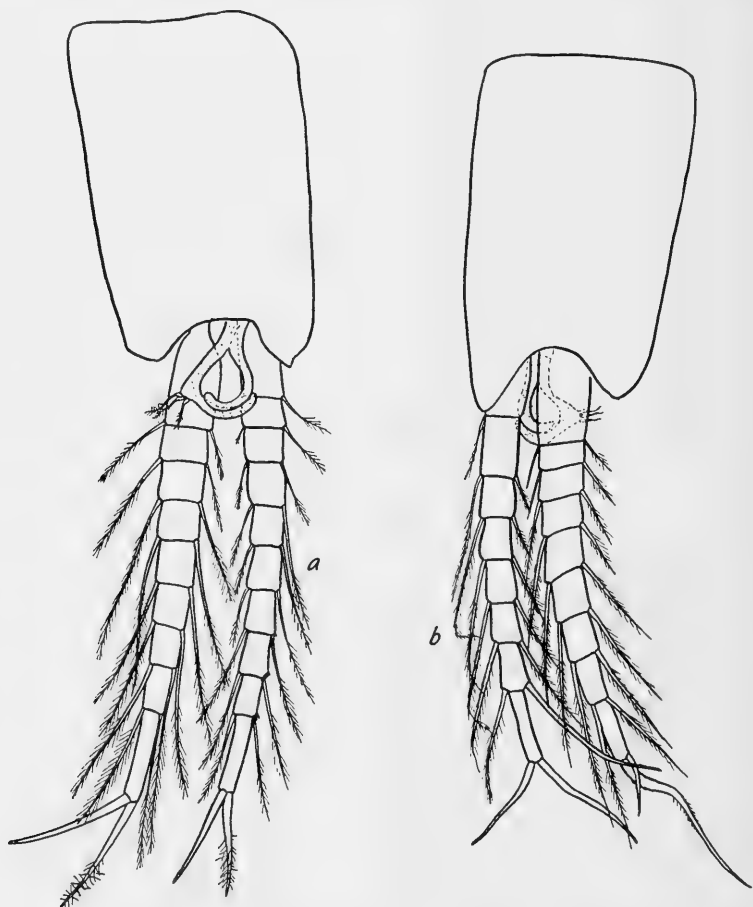
Fig. 2.—*Siriella roosevelti*, n. sp. *a*, third pleopod of the male, × 85. *b*, fourth pleopod of the male, × 85.

spaced occupying more than half of its outer margin; distal joint one and a half times as long as broad.

Telson (fig. 1*c*) three times as long as broad at the base, of the form and shape characteristic of the genus, apex armed with one pair of long and stout spines between which are three small equal spinules

and a pair of plumose setae; lateral margins armed with three strong spines near the base followed by a short smooth portion and then a more or less continuous row of spines to the distal end, the spines arranged in series, especially distally, where there are about five graded smaller spines between each pair of larger spines.

The copulatory lobe of the eighth thoracic limbs of the male has a rather special form which is best described by a figure (fig. 1c).

Length of adult specimens of both sexes, 8 mm.

Remarks.—Among the many species of *Siriella,* this species is most closely allied to *S. pacifica* Holmes. Indeed females of the two species are difficult, if not impossible, to distinguish from one another, but males are readily separated on examination of the third and fourth pleopods. Hansen (1913) has given a full description and figures of *S. pacifica.* On comparing this description and figures with those here given for *S. roosevelti,* the following differences between the two forms emerge:

1. Third pleopod of the male. In *S. pacifica* both rami terminate in a *single* robust spiniform naked seta. In *S. roosevelti* both rami terminate in *two* modified setae, one robust, spiniform, and smooth, the other robust and plumose, much stouter than the plumose setae on the other joints.

2. Fourth pleopod of the male. Endopod in *S. pacifica* has two strong spiniform setae at the apex set at an acute angle to one another, one straight and the other slightly bent. In *S. roosevelti* there are two strong smooth spiniform setae set at a widely divergent angle which is constant and characteristic in all the specimens I have examined. The exopod in *S. pacifica* bears two setae, one short and simple, the other long and very curiously bent in an acute angle. In *S. roosevelti* there are also two setae, one quite short and simple, the other longer and more robust and not bent in the same way as in *S. pacifica.*

The most easily observed character for distinguishing the females of the two species is the number and spacing of the spines on the outer margins of the proximal joint of the outer uropods. In *S. pacifica* there are 14-15 spines, rather closely set, whereas in *S. roosevelti* there are only 8-9 spines somewhat distantly spaced so that, although fewer in number, they occupy about as much of the margin as they do in *S. pacifica.*

S. pacifica and *S. roosevelti* agree with each other and differ from all other species of the genus with the exception of *S. anomala* Hansen, in having *both* rami of *both* the third and fourth pleopods

of the male terminating in modified setae. They can both be distinguished from *S. anomala* by the antennal scale which in the latter species is of very special and peculiar shape in the male.

S. pacifica is known from the Pacific coast of California and is, in point of geographical distribution, the nearest neighbor of *S. roosevelti*.

<p style="text-align:center">Subfamily MYSINAE</p>

<p style="text-align:center">Genus NEOMYSIS Czerniavsky</p>

<p style="text-align:center">NEOMYSIS sp.</p>

Occurrence.—No. 3-38, July 18, 1938, Magdalena Bay, Lower California, Mexico, dredging, boat dredge inside northern point of entrance to bay between Belcher Point and anchorage, 10-15 fathoms, sandy weedy bottom, two females.

Remarks.—Unfortunately, only female specimens are present so that, though I believe they represent a new species, I am unwilling to institute it until male specimens are available. The species belongs to the *Acanthomysis* section of the genus with a short antennal scale, rounded at the apex. It comes nearest to *Neomysis macropsis* Tattersall, *Neomysis pseudomacropsis* Tattersall and *Neomysis columbiae* Tattersall (see Tattersall, 1932 and 1933). It differs from the first two of these species in having more or less normal eyes without specially elongate eyestalks, and from the last of the above species in the absence of the supra-ocular spine on the anterior margin of the carapace. The carapace is broadly rounded anteriorly and somewhat vaulted, very similar to the condition seen in *N. pseudomacropsis* except that perhaps the rostral plate is more produced in relation to the antero-lateral spines of the carapace. The telson resembles most closely that of *N. pseudomacropsis* in that the lateral margins are closely set with spines and the shape is lingular. Male specimens will be awaited with interest so that a full description may be given.

<p style="text-align:center">REFERENCES</p>

ESTERLEY, C. O.
    1914. The Schizopoda of the San Diego region. Univ. California Publ. Zool., vol. 13, No. 1.
HANSEN, H. J.
    1910. The Schizopoda of the *Siboga* Expedition. Siboga-Expéditie, vol. 37.
    1911. The genera and species of the order Euphausiacea with account of remarkable variation. Bull. Inst. Océanogr. Monaco, No. 210.
    1912. The Schizopoda. Mem. Mus. Comp. Zool. Harvard Univ., vol. 35, No. 4.

1913. On some Californian Schizopoda. Univ. California Publ. Zool., vol. 11, No. 9.
1915. The Crustacea Euphausiacea of the United States National Museum. Proc. U. S. Nat. Mus., vol. 48, pp. 59-114.
TATTERSALL, W. M.
1932. Contributions to a knowledge of the Mysidacea of California. Univ. California Publ. Zool., vol. 37, Nos. 13-14.
1933. Euphausiacea and Mysidacea from Western Canada. Contr. Canadian Biol. Fish., vol. 8, No. 15.

THE MALE GENITALIA OF HYMENOPTERA

(WITH 33 PLATES)

BY

R. E. SNODGRASS

Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture

(PUBLICATION 3599)

THE MALE GENITALIA OF HYMENOPTERA

(With 33 Plates)

BY

R. E. SNODGRASS

Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture

THE MALE GENITALIA OF HYMENOPTERA

By R. E. SNODGRASS

Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture

(WITH 33 PLATES)

CONTENTS

I. MORPHOLOGY OF THE MALE GENITALIA OF INSECTS

The study of the external genitalia of male insects has reached a stage at which its current theories should be required to pass a thorough physical examination, or be retired on the ground of incompetence. The facts concerning the ontogeny and the adult structure of the male genital organs are now sufficiently known to permit of tentative generalizations on the homology of the major parts from one order of insects to another. The phylogenetic origin and evolution of the organs, however, is still obscure, and none of the theories that have been proposed as to the primitive nature and possible relation of the genital rudiments to preexisting structures is consistent with all the facts that must be considered in an attempt to solve the problem.

The work here presented is a contribution from the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, and the writer is indebted for most of the material used and for all the determinations of species to the various specialists in Hymenoptera of the taxonomic staff of the Bureau.

The paired coelomic sacs of primitive arthropods undoubtedly opened by means of coelomoducts discharging through coelomopores on the mesal aspects of the bases of the segmental appendages, as do the embryonic coelomic sacs of Onychophora, and their persisting remnants, the nephridia. Any pair of coelomic sacs and their ducts that became specialized as genital outlets, therefore, opened primarily also on the bases of a corresponding pair of appendages. This primitive condition (fig. 1 A) is retained in many modern arthropods, as in numerous Crustacea and Diplopoda. The particular pair of coelomic sacs that have become genital ducts pertains to different somites in different arthropod groups, and may be different in the two sexes within a group. *Primary paired genital ducts, therefore, are homologous only where they open on homologous somites.* Among the Crustacea and Diplopoda having the genital apertures on the bases of the legs, the male ducts usually open through a pair of small penial processes (fig. 1 A, *Pen*) on the mesal surfaces of the genital coxae. In some species in each of these groups, however, and in Onychophora and Symphyla, the ends of the ducts appear to have migrated mesally from the appendage bases to the venter of the genital segment, where they open through a common median orifice or on a single median penis (B, *Pencn*).

With the insects, evidence from embryogeny and from the adult relation of the vasa deferentia to the nerves of the eleventh abdominal

segment shows that the primary genital ducts of the male must have
opened on the *tenth* segment of the abdomen. In early embryonic
stages of certain Orthoptera the terminal mesodermal ampullae of
the ducts lie within the vestigial appendages of the tenth segment
(fig. 1 C, *Appd*). This primary relation of the ducts to the appendages
clearly suggests that the mesodermal vasa deferentia of primitive in-
sects opened on the bases of the tenth pair of abdominal limbs, where
probably, as in many adult Crustacea and Diplopoda (fig. 1 A), they
discharged through small penes located on the mesal surfaces of the
coxopodites.

Paired penes giving exit individually to the genital ducts occur
among the Hexapoda in Protura, Ephemeroptera, and in certain Der-
maptera. The penes of Ephemeroptera appear to belong to the tenth
abdominal segment (see Snodgrass, 1936; Qadri, 1940). They may
be supposed to be either the stumps of former appendages of this
segment that primarily contained the outlets of the ducts, or a pair
of true penes that have persisted after the disappearance of the ap-
pendages. Inasmuch as in some ephemeropterid species the penes are
united in a single median organ containing the outlets of both ducts,
the second supposition may be the more plausible, since a median union
of the penes takes place in some Crustacea and Diplopoda. The paired
genital organs of Dermaptera assume an adult structure quite different
from that in Ephemeroptera, but according to Qadri (1940) they have
the same origin from a pair of penis lobes of the tenth segment that
give exit individually to the paired genital ducts. The paired penes
of Protura would appear to have no homology with those of Ephem-
eroptera and Dermaptera because they pertain to the eleventh ab-
dominal segment.

The single median genital organ of the male usually present in
insects other than members of the three groups mentioned above is
developed in a manner different from that of the production of a
median penis by the union of a pair of primitive penes. This second
type of median genital organ, distinguished by the writer as the *phallus*,
is formed by the union of a pair of primary genital lobes that at no
time in their known history contain the outlets of the genital ducts,
and which, therefore, do not have the distinctive feature of a pair of
primitive penes. The single outlet duct of the phallus is formed as
a median invagination of the body wall *between* the bases of the pri-
mary component lobes of the definitive organ. Anatomically the
phallus appears usually to be situated between the ninth and tenth
abdominal segments, but in most insects its rudiments arise on the

ninth segment, and its adult musculature pertains to this segment. Where the embryonic history of the vasa deferentia has been followed in connection with the development of the phallus, it is observed that the terminal ampullae of the ducts leave their primary points of attachment on the ventral ectoderm of the tenth abdominal segment, or in
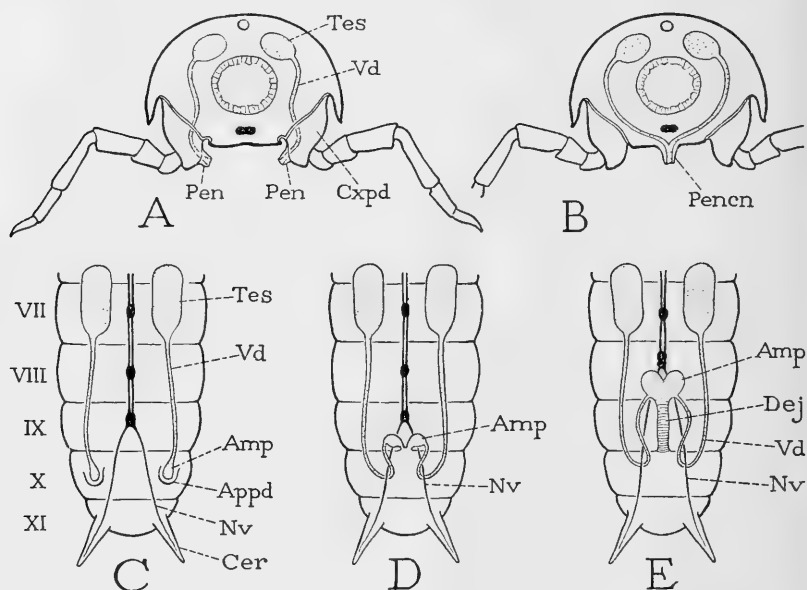
FIG. I.—Evolution of the male genital ducts and outlets, diagrammatic.

A, theoretical primitive position of arthropod genital apertures on mesal surfaces of coxopodites of a pair of segmental appendages, the male ducts opening through a pair of penes (*Pen*); the actual condition in many Crustacea and Diplopoda. B, derived condition in which the male ducts discharge through a single median penis. C, early embryonic condition in certain Orthoptera in which the ampullae of vasa deferentia lie within appendage rudiments of tenth abdominal segment. D, later embryonic stage in which ampullae have migrated mesally and forward beneath nerves of cerci (*Nv*) to base of tenth segment. E, adult condition, with ampullae united on anterior end of median ectodermal ductus ejaculatorius (*Dej*), and vasa deferentia looped beneath cercal nerves.

Amp, terminal ampulla of vas deferens; *Appd,* vestigial appendage of tenth abdominal segment; *Cer,* cercus; *Cxpd,* coxopodite; *Dej,* ductus ejaculatorius; *Nv,* cercal nerve of eleventh abdominal segment; *Pen,* penis; *Pencn,* median penis, probably formed by conjunction of a pair of lateral penes; *Tes,* testis; *Vd,* vas deferens; *VII-XI,* seventh to eleventh abdominal segments.

the appendage rudiments of this segment, and migrate mesally and forward to the base of the tenth segment or into the posterior part of the ninth (fig. I D). Here a median ectodermal ingrowth is formed that unites with the ampullae and becomes the definitive ductus ejaculatorius (E, *Dej*). The vasa deferentia, through having their pos-

terior ends carried mesally and forward, come to be looped ventrally around the cercal nerves (*Nv*) of the eleventh abdominal segment. This phase of embryonic development may be interpreted literally as phylogenetic recapitulation.

The phallic rudiments usually first appear in nymphal or larval stages as a pair of minute papillae formed as outgrowths of the body wall immediately laterad of the site where the ductus ejaculatorius will be formed by invagination between their bases (fig. 2 A, *Phm*). In orthopteroid insects the exact segmental relation of the primary phallic lobes is difficult to determine; the lobes originate behind the sternum or "coxal plates" of the ninth abdominal segment, but the inflected poststernal membrane usually belongs to the segment preceding it. Qadri (1940) says the genitalia rudiments of Orthoptera probably represent appendicular outgrowths of the tenth segment, and he asserts that the ductus ejaculatorius belongs to this segment. In Homoptera it is generally stated (Pruthi, 1924a; George, 1928; Metcalfe, 1932a) that the phallic rudiments pertain to the ninth abdominal segment. In holometabolous larvae the genital papillae unquestionably first appear on the posterior part of the venter of the ninth segment, where usually they become sunken in a "peripodal" pocket of the epidermis beneath the cuticle.

The primitive nature of the primary phallic lobes has been the subject of much discussion and of various theories. Two opinions are current: one, that the lobes are merely outgrowths of the integument at the sides of the gonopore developed specifically to subserve the intromittent function; the other, that they are derivatives of segmental appendages secondarily adapted to the functions they assume. At the ontogenetic stage when the ampullae of the vasa deferentia lie between the bases of the phallic lobes, where presumably at some corresponding early phylogenetic stage they opened to the exterior (fig. 2 A), the relation of the associated structures suggests a pair of primary genital ducts opening at the bases of a pair of segmental appendages (fig. 1 A). It has been claimed, in fact, by Else (1934) that the phallic lobes of the grasshopper *Melanoplus* are the appendage rudiments of the tenth abdominal somite, which in the embryo follow the genital ducts in their migration to the base of the tenth segment, where they unite and develop into the phallic organ of the adult. According to Roonwal (1937) the phallic rudiments are formed in *Locusta* by the union of the ninth and tenth abdominal appendages.

The concept that the phallic lobes are the appendages of the tenth abdominal segment encounters no difficulty in apterygote or exopterygote insects, in which the tenth segment otherwise is without

appendages; but it cannot be carried over to holometabolous insects, since in many of these there are on the tenth abdominal segment of the larva well-developed appendages that take no part in the formation of the genital organ, the rudiments of which are present at the same time in the same species as a pair of small disks on the venter of the ninth segment (fig. 3 A). There is no evidence, either embryological or anatomical, that the numerical tenth abdominal segment of these insects is not the true tenth somite, though the terminal appendage-bearing segment of holometabolous larvae might logically seem to be the homolog of the cercus-bearing eleventh somite of more generalized insects.

On the other hand, it is also impossible to see in postembryonic stages of insects any relation of the phallic rudiments to the appendages of the ninth abdominal segment, since the latter form the "coxal plates" of the definitive ninth sternum. These plates are shown by Sharif (1937) in the larva of the rat flea (fig. 2 H, *cxpl*) to be developed entirely independent of the phallic lobes, which are sunken in a pocket of the venter of the ninth segment. In *Lepisma,* according to Lindsay (1940), the genital rudiments of the male that eventually form the penis appear first in the eighth instar as two small lobes on the intersegmental membrane at the base of the cleft in the ninth sternum. The cleft "ninth sternum" of Thysanura, however, becomes the completely separated stylus-bearing "coxal plates" of the ninth segment, which have no direct connection with the definitive genital organ. Also in *Machilis* it is shown by Qadri (1940) that the primary phallic lobes develop independently of the ninth-segment appendages.

The embryonic abdominal appendages of insects can represent at most only the bases of former limbs, since it is to be presumed that the abdominal telopodites were all lost before the phallus was evolved. There remain of the abdominal limbs, therefore, only the bases and their appurtenances, such as styli, eversible vesicles, and gonapophyses. The phallic lobes are not styli or gonapophyses, since in some species of the thysanuran *Machilis* both these structures are present on the genital segment in addition to the phallic organ, nor can they be eversible vesicles because they are never borne on the plates representing the limb bases. It is true that the phallic rudiments in early stages of development much resemble the parts of the ovipositor developed on the ninth abdominal segment of the female, but the rudiments of the ovipositor clearly are derivatives of abdominal limbs, as is evident in Thysanura and in nymphal Blattidae in which the ninth-segment elements of the ovipositor bear a pair of styli. In conclusion,
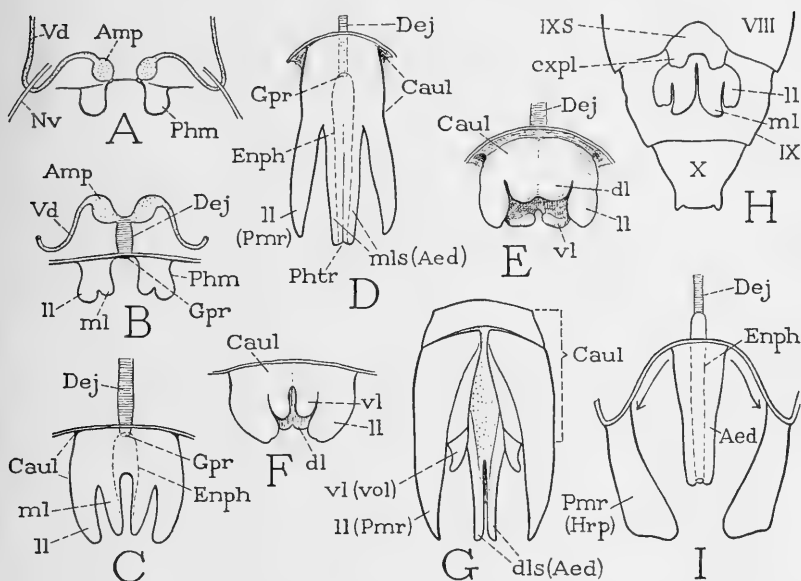
FIG. 2.—Development of the phallus, diagrammatic.

A, primary phallic lobes, or phallomeres (*Phm*), with ampullae of vasa deferentia at their bases, where presumably they opened at a corresponding phylogenetic stage. B, ductus ejaculatorius (*Dej*) formed by ingrowth of body wall between bases of phallic rudiments, the latter divided distally into secondary lateral and median lobes (*ll, ml*). C, later stage of phallic development: distal lobes elongated, bases of primary lobes united to form a common phallobase, or caulis (*Caul*), enclosing an endophallic chamber (*Enph*), into which opens the ductus ejaculatorius. D, coleopterous type of mature phallus with common base supporting a pair of free lateral lobes (parameres, *Pmr*) and united median lobes forming an aedeagus (*Aed*) on which the endophallus opens through a phallotreme (*Phtr*). E, orthopterous type of phallus with a common base and three pairs of secondary terminal lobes (dorsal, lateral, and ventral). F, hymenopterous type of phallus in pupal stage, resembling the orthopterous type (E) in having three pairs of terminal lobes. G, mature hymenopterous phallus with common base (*Caul*) bearing free lateral parameral lobes (*Pmr*), free ventral volsellar lobes (*vol*), and united dorsal aedeagal lobes (*Aed*). H, terminal abdominal segments of male prepupa of a flea (simplified from Sharif, 1937), showing four-lobed phallus of ninth segment, and independent coxal plates (*cxpl*) of ninth sternum. I, phallic structure of most Rhynchota and holometabolous insects, in which the movable claspers (harpagones, *Hrp*) appear to be the parameres entirely separated from the aedeagus.

Aed, aedeagus; *Amp,* ampulla of vas deferens; *Caul,* phallobase, or caulis; *cxpl,* coxal plates of ninth abdominal sternum (*IXS*); *Dej,* ductus ejaculatorius; *dl,* dorsal lobe of immature phallus; *dls,* united dorsal lobes of mature phallus; *Enph,* endophallus; *Gpr,* gonopore; *Hrp,* harpago; *ll,* lateral lobe of immature phallus; *ml,* median lobe of immature phallus; *mls,* united median lobes of mature phallus; *Nv,* cercal nerve of eleventh segment; *Phm,* phallomere, or primary phallic lobe; *Phtr,* phallotreme; *Pmr,* paramere; *Vd,* vas deferens; *vl,* ventral lobe of immature phallus; *vol,* volsellar lobe of mature phallus.

therefore, concerning the origin of the insect phallus, we can say only that the facts at present known about the development of the organ are not sufficient to warrant any definite statement, but that they appear to favor the view that the phallus is an independent genital structure. The male genital organ of insects has no homolog with a genital function in any other arthropod group.

The ontogenetic origin of the phallus from a single pair of primary phallic lobes has been observed in nearly all the larger orders of insects from Thysanura to Hymenoptera, with the exception of Mecoptera and Diptera. In the Blattidae and Mantidae the lobes develop individually into variously modified genital structures. In most of the other orders each primary lobe, or *phallomere* (fig. 2 A, *Phm*), first branches distally into two or three secondary lobes (B), and then the undivided proximal parts unite (C) to form a common basal stalk, the *phallobase,* or *caulis* (*Caul*). When, as in the majority of insects, each primary lobe forms only two secondary lobes (B), the immature phallus (C) has a pair of lateral distal lobes (*ll*) and a pair of median lobes (*ml*) ; if each primary lobe gives rise to three secondary lobes, the composite organ (E, F) bears distally a pair of lateral lobes (*ll*), a pair of dorsal lobes (*dl*) corresponding with the median lobes in the first case, and a pair of ventral lobes (*vl*). In Rhynchota and all holometabolous insects in which the phallic development is known, the median lobes (C, *ml*), or the corresponding dorsal lobes in six-lobed forms (F, *dl*) unite and produce a single median structure, which is the *aedeagus* of the adult (D, G, I, *Aed*). The lateral lobes of Homoptera, Coleoptera, and Hymenoptera become the *parameres* (*Pmr*). The ventral lobes, present in Orthoptera (E, *vl*) and Hymenoptera (F), are transformed in Hymenoptera into the movable volsellar lobes of the mature phallus (G, *vol*). The six-lobed type of phallic structure appears to be fundamental in Orthoptera, as it is in Hymenoptera, but in the Orthoptera (E) there is little uniformity in the development of the lobes, and only in Acrididae do the lobes of the dorsal pair unite partially to form an aedeagus (see Snodgrass, 1937).

The basal union of the primary phallic lobes takes place dorsally and ventrally, thus leaving within the caulis an open space, the walls of which constitute an inner phallic sac, or *endophallus* (fig. 2 C, *Enph*), into which the ductus ejaculatorius (*Dej*) discharges proximally through the original gonopore (B, C, *Gpr*). In most Orthoptera the endophallus remains widely open distally between the terminal phallic lobes (E) ; but in insects in which the median or dorsal lobes

unite to form an aedeagus, the endophallus is extended into the latter (D, *Enph*), and its distal aperture, the *phallotreme* (*Phtr*), is carried out upon the aedeagus, which becomes specifically the intromittent element of the phallus.

The mature external male genital apparatus of Rhynchota and the holometabolous orders presents two types of structure. In Coleoptera and Hymenoptera, as shown by Pruthi (1924), Metcalfe (1932), and Zander (1900), the primary phallic lobes are not completely divided into secondary parameral and aedeagal lobes (fig. 2 C, F), so that the adult phallus in these orders (D, G) is a compact organ with a common basal stalk, the caulis, supporting the aedeagus and the parameres. On the other hand, in Rhynchota, according to Pruthi (1924a, 1925), George (1928), Metcalfe (1932a), and Rawat (1939, 1939a), and in Trichoptera and Lepidoptera, according to Zander (1901, 1903), the parameral lobes are entirely split off from the aedeagus, and are transposed laterally to the annulus of the ninth abdominal segment (fig. 2 I), where they are said to become the variously developed, independently musculated, appendicular genital organs commonly known as the *claspers, valvae, harpes,* or *harpagones.*

The evidence of phallic derivation of the claspers appears to be conclusive in Homoptera, and in this group the claspers (parameres) are associated with the base of the aedeagus. On the other hand, in most Heteroptera, Mecoptera, most Trichoptera, Lepidoptera, and Diptera they are independently articulated on the lateral walls or the "coxal plates" of the ninth abdominal segment. It is claimed by Mehta (1933), in opposition to Zander (1901), that the "valvae" (harpes) of Lepidoptera arise independently from the lobes that form the aedeagus, and are therefore not phallic structures. The observed fact, of course, may be interpreted as an ontogenetic elision. However, it should be noted that Zander's (1903) contention that the "valvae" of Trichoptera are offsets from the primary phallic lobes is based on studies of limnophilid species alone, particularly *Limnophilus bipunctata,* and according to Zander's own statement the "valvae" of the Limnophilidae have an entirely different structure from the movable musculated claspers of other Trichoptera, since they are immovable lobes of the lateral walls of the "penis pouch" and are devoid of muscles. It must be admitted, therefore, that we still have no conclusive evidence as to the nature of the movable musculated claspers borne on the lateral walls or on the "coxal plates" of the ninth abdominal segment, such as occur in Heteroptera, Mecoptera, Trichoptera other than Limnophilidae, Lepidoptera, and Diptera. These

organs have been regarded by some students of comparative anatomy as representing the ninth-segment styli of Ephemeroptera and Orthoptera (see Snodgrass, 1935a).

II. THE TERMINAL BODY SEGMENTS AND THE PHALLUS OF HYMENOPTERA

The abdomen of Hymenoptera contains at least 10 segments, here designated segments I to X regardless of whether the first segment is retained in the abdominal region (Chalastogastra), or becomes an integral part of the definitive thorax (Clistogastra).

THE TERMINAL BODY SEGMENTS

Ten abdominal segments are distinct and well developed in most hymenopterous larvae (figs. 3 A, 4 A), the last segment bearing the anus (An) and, in Chalastogastra, the last pair of abdominal larval legs, or pygopods (fig. 3 A, D, Pgp). It is reasonable to assume, however, that the numerical tenth segment may include somites X and XI. The larva gives little positive evidence as to the composition of this segment, though the latter is without doubt mostly somite X. In chalastogastrous larvae (fig. 3 D) it contains the muscles of the pygopods, the last segmental set of ventral longitudinal muscles, and the dilator muscles of the narrow exit channel of the rectum, while on its base are attached the evacuator muscles of the rectal sac. The posterior surface of the terminal segment is deeply cleft transversely by the wide anal aperture (An) between a rounded supra-anal lobe (a) and a similar subanal lobe (b).

With the transformation of the larva to the pupa (fig. 3 B) the upper part of the ninth abdominal segment is greatly shortened, though the tergum (IXT) is expanded laterally in the female, and the terminal segment is much reduced in size. The anal lobes (a, b), however, are still prominent and enclose between them the transverse anal cleft (An); but proximal to the anal lobes there is differentiated a narrow area (c) within which will be formed the tergites of the tenth segment of the adult (C, XT), and at the lower ends of this area in the pupa (B) at the base of the subanal lobe there is on each side a small but distinct lobe (d). The larval legs of the tenth segment, on the other hand, have completely disappeared, unless they are represented by the small lobes (d) just noted.

By removing the loosened cuticula in a late pupal stage the immature imaginal structure is revealed (fig. 3 C). The ninth tergum (IXT) has the same shape as in the pupa. Immediately behind its

narrow dorsal part are the small lateral tergites of the tenth segment (XT) formed in the region of the pupa (B, c) differentiated proximal to the bases of the persisting anal lobes. Each tergal plate of the imaginal tenth segment bears ventrally on its posterior margin a minute pygostyle (C, Pgs), which normally lies exactly within the small lobe of the pupal skin (B, d) at the base of the subanal lobe,
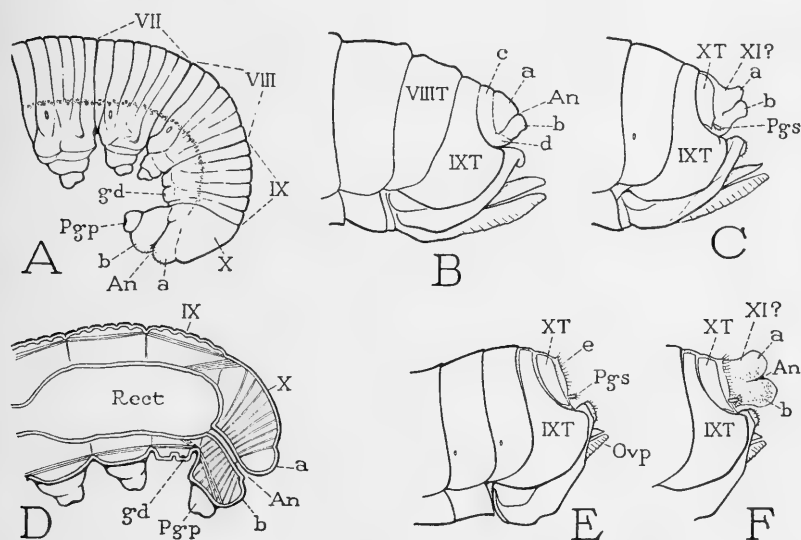
FIG. 3.—Postembryonic transformations of the terminal abdominal segments of a female sawfly, *Gilpinia polytoma* (Htg.).

A, posterior segments of mature larva. B, same segments of pupa. C, corresponding segments of immature imago within pupal cuticula. D, diagrammatic section of posterior larval segments. E, end of abdomen of mature imago, usual condition. F, terminal segments with "anal vesicle" (apparent eleventh segment) everted.

a, supra-anal lobe; *An*, anus; *b*, subanal lobe; *c*, dorsum of tenth segment; *d*, pupal lobe of tenth segment covering imaginal pygostyle; *e*, posterior marginal membrane of tenth tergum; *gd*, genital disk of ninth segment; *Ovp*, ovipositor; *Pgp*, pygopod; *Pgs*, pygostyle; *Rect*, rectum; *VII-XI*, seventh to eleventh abdominal segments.

and is therefore evidently represented by this lobe (d) in the pupa. The anal lobes now appear to belong to a distinct region lying posterior to that of the tenth tergal plates (C). In the fully matured imago (E) the anal lobes are ordinarily not in evidence; the dorsum of the abdomen ends with a short membranous fold (e) fringed with hairs bordering the tenth tergal sclerites, beneath which is a vertical membranous area containing a transverse exit aperture of the alimentary tract. However, an occasional specimen may be found in

which there has been everted from this opening a large vesicle on which the rectum opens through a transverse cleft between bulging dorsal and ventral lobes (F). This everted structure is the region of the anal lobes of the immature imago and the pupa, which ordinarily in the adult is concealed by invagination. The functional anal opening of the adult, therefore, is the aperture of the invagination cavity formed by the retraction of the anal lobes, but the true anus is the opening of the rectum into the anterior end of this cavity. In the male of the ichneumonid *Megarhyssa lunator* the everted anal vesicle is seen to bear a pair of small setigerous appendages similar to the pygostyles of the tenth segment (pl. 4 O, P, *Cer?*).

A consideration of the facts above described leads to the conclusion that the pygostyles of adult Hymenoptera belong to the tenth abdominal segment, and that they are possibly derived from the pygopods (tenth-segment appendages) of the larva. It is suggested, moreover, that the eversible anal vesicle of the adult (fig. 3 F), or the region of the external anal lobes of the pupa (B) and the larva (A), represents the eleventh abdominal segment combined with the tenth. The setigerous appendages of the anal vesicle in the male of *Megarhyssa lunator* (pl. 4 O, P, *Cer?*), therefore, might be regarded as true cerci of the eleventh segment. Though these appendages have not been observed in any other hymenopterous species, and are not present in the female of *Megarhyssa,* the rectum of all adult Hymenoptera opens into a terminal invagination chamber, within which the lips of the anus may form a pair of distinct anal lobes.

THE PHALLUS AND PHALLIC NOMENCLATURE

The male genital organ of Hymenoptera is usually of relatively large size, and can be easily extracted from the genital chamber at the end of the body, either in a fresh insect or in a dry specimen after relaxing or boiling in water. The general structure of the phallus is remarkably consistent throughout the order, and in a comparative study little difficulty is encountered in identifying corresponding parts. Special types of modification, however, are in many cases characteristic of superfamily groups, and details of structure undoubtedly will be found to be diagnostic of species among the Hymenoptera as in most other insect orders.

The development of the hymenopterous phallus from a pair of primary phallic rudiments on the posterior part of the venter of the ninth abdominal segment in the larva has been described by Seurat (1899) in the braconid *Dorcytes,* by Michaëlis (1900) in *Apis,* by

Zander (1900) in *Vespa, Bombus,* and *Apis,* and by Boulangé (1924) in *Sirex.*

The first rudiments of the male genital organ of *Vespula maculata* appear in a late larval stage, probably the last larval instar, as a pair of slight thickenings in a small oval disk of the integument near the posterior margin of the venter of the ninth abdominal segment (fig. 4 A, B, C, *gd*). By removing the cuticula containing the genital disk
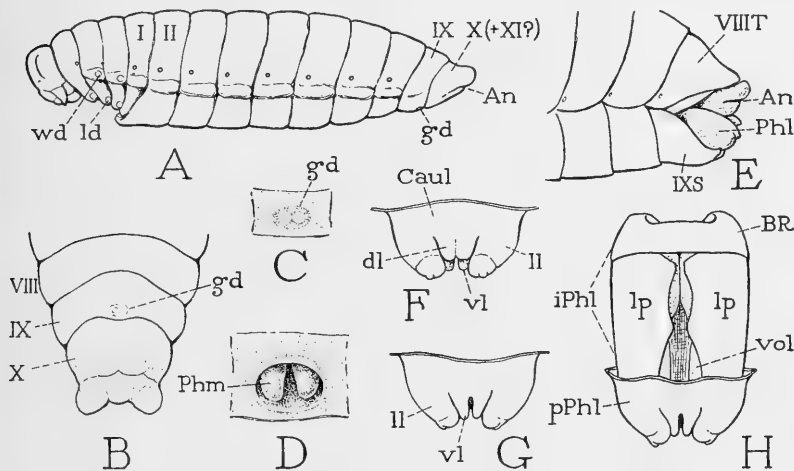
FIG. 4.—Postembryonic development of the phallus of *Vespula maculata* (L.).

A, mature larva. B, posterior end of same, ventral view, showing genital disk on ninth segment. C, piece of cuticula from same containing genital disk. D, body wall beneath genital disk, exposed by removal of cuticula, showing pocket containing the phallic rudiments (*Phm.*). E, end of abdomen of pupa, showing large external phallus (*Phl*). F, pupal phallus, dorsal. G, same, ventral. H, phallus of immature imago (*iPhl*) exposed by removal of pupal cuticula, with terminal lobes still in corresponding parts of pupal phallus (*pPhl*).

An, anus; *BR,* basal ring; *Caul,* phallobase, or caulis; *dl,* dorsal lobe of immature phallus; *gd,* genital disk; *iPhl,* imaginal phallus; *ld,* leg disk; *ll,* lateral lobe of immature phallus; *lp,* parameral plate; *Phl,* phallus; *Phm,* primary phallic lobe, phallomere; *pPhl,* pupal phallus; *vl,* ventral lobe of immature phallus; *vol,* volsellar lobe of mature phallus; *wd,* wing disk.

(C), there is exposed beneath the latter an oval pit of the epidermis with a pair of minute papillae emerging from its inner wall (D). The papillae are the primary phallic lobes, or phallomeres (*Phm*), sunken into a "peripodal" pocket of the epidermis. The early development of the phallic lobes of *Vespa germanica* is described by Zander (1900) as follows: Each rudiment becomes first divided distally by a vertical cleft, and thus differentiated into a basal part and two secondary terminal lobes, one lobe being lateral and the other mesal, but soon there is found a third dorsomesal lobe, giving the appendage

finally a tripartite structure. Before pupation the undivided proximal parts of the two appendages coalesce, and the dorsomesal lobes unite in a thick median structure. The newly formed phallus, thus derived from two entirely separate rudiments, now consists of a thick basal stalk, of a pair of lateral parameral lobes ("valvae externae"), a median aedeagal lobe, and a pair of mesoventral volsellar lobes ("valvae internae"). Meanwhile, the mouth of the "peripodal" cavity has enlarged, and, with the pupal ecdysis, the phallus is extruded and assumes an external position on the body of the pupa.

The pupal phallus of *Vespula maculata* appears as a large organ partially exposed at the end of the body projecting between the proctiger above and the ninth sternum below (fig. 4 E, *Phl*). It consists of a broad base (F, *Caul*), a pair of thick lateral lobes (*ll*), a short median dorsal lobe (*dl*) still showing evidence of its dual composition, and a pair of slender ventral lobes (*vl*). The form and size of the pupal phallus are retained without change in the pupal cuticula throughout the life of the pupa, but at an early stage of the imaginal development within the pupal skin the imaginal phallus increases greatly in size and soon takes on its final form. In an old pupa the imaginal organ (H, *iPhl*) has extended far forward from the base of the pupal organ (*pPhl*), so that only its terminal lobes lie within the latter, but the relationships show clearly that the lateral lobes of the pupal phallus become the parameres of the adult, the composite median dorsal lobe the aedeagus, and the ventral lobes the volsellar lobes. From the base of the imaginal organ there is set off a distinct basal ring (*BR*), which is said by Zander to be differentiated from the proximal part of the pupal phallus by a secondary growth of the epidermis in this region.

The development of the phallus in *Sirex* and in *Bombus,* as described respectively by Boulangé (1924) and by Zander (1900), differs in no essential respect from that of *Vespa,* except for such differences as exist in the adult structure of the organ in these species. The volsellae are greatly reduced in *Bombus;* and in most of the Apoidea, including *Bombus,* the aedeagus takes on a tripartite form, as will be shown later.

The mature hymenopterous phallus is typically a strongly sclerotized, elongate structure (fig. 5 A, B) having a cylindrical base, the *caulis* (*Caul*), from which arise distally the median *aedeagus* (*Aed*) and the lateral *parameres* (*Pmr*). Between the bases of the parameres and the aedeagus there is usually on each side one or two pairs of volsellar lobes (B, *cus, dig*), collectively the *copulatory ossicles* of

Crampton (1919). In the base of the caulis is an annular sclerite, the *basal ring* (*BR*), by which the phallus is attached to the wall of the genital chamber. The parameres are usually continuous from a pair of lateral *parameral* plates of the caulis (*lp*), though in many species they are movably articulated on the latter. The volsellar lobes are supported on a pair of ventral *volsellar plates* (B, *lv*), which either lie horizontally adjoining the ventral edges of the parameral plates (C, *lv*), or are inflected dorsally on the latter in a deep concavity on the ventral side of the caulis (D). The aedeagus contains a pair of lateral *aedeagal sclerites,* or *penis valves* (A, B, *pv*), which are extended proximally into the lumen of the caulis as a pair of *aedeagal apodemes* (G, *apa*). The phallotreme is either ventral or terminal on the aedeagus (B, G, H, I, *Phtr*). The terms "dorsal" and "ventral" as used above must be understood to be reversed in their application to Tenthredinoidea and certain species of Xyelidae, in which the entire phallus is normally inverted.

The phallic nomenclature adopted in this paper is partly taken from other sources, but a number of new terms are introduced in order to give designations better adapted to specific description. The history of the genital nomenclature in Hymenoptera has been so fully reviewed by Boulangé (1924) and by Beck (1933) that it need not be repeated here. The principal synonymy of the terms used in this paper, however, is given in the following general descriptions of the parts of the phallic organ.

THE PHALLOBASE, OR CAULIS (*Caul*).—The caulis is the basal stalk of the phallus bearing the free terminal lobes (fig. 5 A, B). On its base are inserted the muscles that move the phallus as a whole, and its lumen contains the intrinsic phallic muscles, including muscles of the aedeagus, of the volsellae, and of the parameres when the last have muscles. The caulis is often regarded as consisting of two segments, the basal ring, or "gonocardo," and a distal segment, or "gonostipites" (cupule and spathe of Audouin, 1821), but its five sclerites, namely, the basal ring (*BR*), the two parameral plates (*lp*), and the two volsellar plates (B, *lv*), constitute the anatomical units most useful for descriptive purposes. The dorsal surface of the caulis (A) between the parameral plates is usually membranous and continuous with the dorsal wall of the aedeagus. The ventral surface (B) likewise is generally membranous between the volsellar plates and continuous with the ventral wall of the aedeagus, but it is flat or concave according as the volsellar plates are horizontal (C) or inflected upward against the mesal surfaces of the parameral plates

2

(D, E). The caulis is variable in length and sometimes it is greatly reduced by a proximal extension of the clefts between the aedeagus and the parameres. Its lateral parts may be produced at the sides of the aedeagus into basiparameral lobes bearing the parameres. The caulis and the parameres together are analogous to the "tegmen" of the coleopterous phallus as defined by Sharp and Muir (1912).

THE BASAL RING, OR LAMINA ANNULARIS (*BR*).—*Cupule* Audouin (1821); *pièce basilaire* Dufour (1841); *cardo* Thomson (1872), Schmiedeknecht (1882-'84), Zander (1900); *lamina annularis* Verhoeff (1893a); *plaque basilaire* Seurat (1899); *gonocardo* Crampton (1919), Peck (1937); *sclérite accessoire,* or *cardo* Boulangé (1924); *basal ring* Beck (1933), Snodgrass (1935).

The basal ring is typically an annular sclerite in the base of the caulis surrounding the foramen by which the lumen of the phallus communicates with the general body cavity. The foramen may be directed anteriorly, anterodorsally, or anteroventrally, and sometimes it lies almost in the dorsal or ventral plane of the phallus. The basal ring is correspondingly of greater width above or below, and it may be incomplete; sometimes it is reduced to a narrow band, but only rarely is it completely suppressed. The ventral anterior margin of the ring often bears a small median process or knob, the *gonocondyle* of Crampton (1919), on which muscles are attached (fig. 6 A, *gc*). According to Zander (1900) the basal ring of *Vespa germanica* is differentiated relatively late in development as a thickening of the epidermis at the base of the phallus. As contended by Verhoeff (1893a) the annular sclerite is evidently a special feature of the hymenopterous phallus, and has no homolog in other insects.

The extrinsic phallic muscles all arise on the sternal plate of the ninth abdominal segment and are inserted on the basal ring of the phallus. Boulangé (1924) has shown that there are generally present three pairs of these muscles (fig. 6 A, *1, 2, 3*), two of which insert on the gonocondyle, and one on the ventrolateral margins of the basal ring. In species in which the phallus permanently assumes an inverted position these muscles are twisted upon one another to the right or the left according to the direction of the phallic revolution.

THE LAMINAE PARAMERALES, OR BASIPARAMERES (*lp*).—Basal parts of *forceps* Dufour (1841); *stipites* Thomson (1872), Zander (1900); *gonostipites* Crampton (1919), Peck (1937); *pièces principales* or *stipites* Boulangé (1924); *coxopodites* Beck (1933).

The parameral plates (fig. 5 A, B, *lp*) are usually regarded as the basal parts of the parameres (*Pmr*), since they are generally con-

tinuous with the outer walls of the latter. It should not be overlooked, however, that anatomically these plates are sclerotizations of the walls of the caulis, and that their continuity with the parameres is incidental to the fact that the parameres are outgrowths of the caulis.
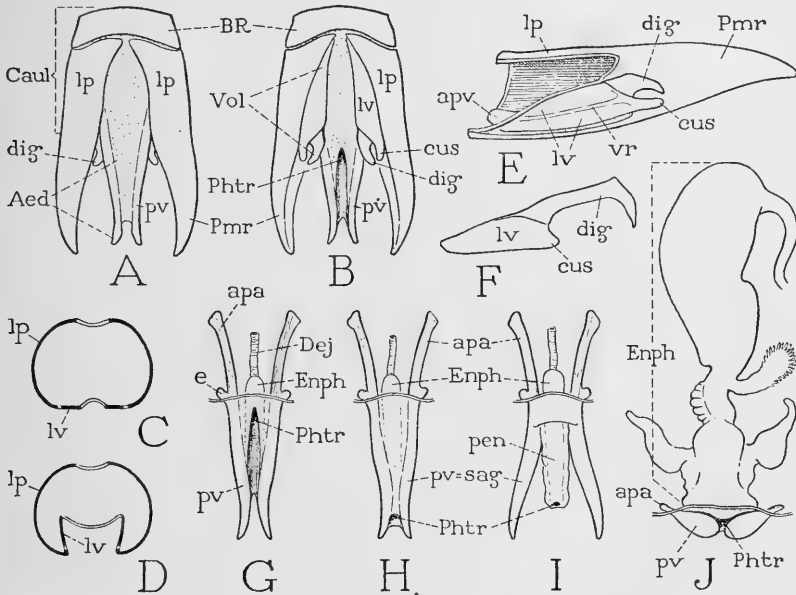
FIG. 5.—Structure of the hymenopterous phallus, diagrammatic.

A, B, typical form and structure of the ectophallus in dorsal and ventral view. C, transverse section of caulis with horizontal volsellar plates (B, *lv*). D, section of caulis with volsellar plates inflected dorsally on lower edges of parameral plates (E). E, mesal view of right parameral plate (*lp*) and paramere, with volsellar plate (*lv*) inflected dorsally on lower edge of parameral plate. F, volsella with reduced cuspis and large digitus. G, usual structure of the aedeagus, ventral view, with phallotreme at base of ventral channel. H, same, with subapical phallotreme. I, phallic structure characteristic of most bees, in which the penis valves (*pv*), known as sagittae (*sag*), are separated from a median penis (*pen*) bearing the phallotreme. J, phallus of the honey bees (*Apis*), in which the ectophallus is reduced and the endophallus (*Enph*) greatly enlarged.

Aed, aedeagus; *apa,* aedeagal apodeme; *apv,* basal apodeme of volsella; *BR,* basal ring of caulis; *Caul,* phallobase, or caulis; *cus,* cuspis of volsella; *Dej,* ductus ejaculatorius; *dig,* digitus of volsella; *e,* basal process of aedeagal apodeme; *Enph,* endophallus; *lp,* lamina parameralis; *lv,* lamina volsellaris of caulis; *pen,* median lobe, or penis, of aedeagus of bees; *Phtr,* phallotreme; *Pmr,* paramere; *pv,* lamina aedeagalis, or penis valve; *sag,* sagitta, lateral process of aedeagus of bees (free penis valve); *Vol,* volsella.

Moreover, in most of the Chalastogastra and many of the Clistogastra the parameres are demarked from the parameral plates of the caulis by distinct lines of flexibility or articulation. Dorsally (A) the parameral plates are usually separated from each other by a median

membranous area of the caulis wall, though often the basal angles are united by a sclerotic bridge, and sometimes the entire dorsal margins are contiguous, or even confluent. Ventrally (B) the parameral plates are either closely connected by membrane with the volsellar plates or are directly united with them. In various unrelated chalastogastrous and clistogastrous species the posteromesal areas of the dorsal parts of the parameral plates are produced into lobes (fig. 6 A, *pa*) termed *parapenes* by Crampton (1919). In strophandrious forms the parapenial lobes are secondarily on the under side of the phallus.

Four pairs of intrinsic phallic muscles extend between the basal ring and the parameral plates, which are shown by Boulangé (1924) to be of general occurrence in the Hymenoptera. The muscles of one pair arise on the gonocondyle or median ventral part of the basal ring (fig. 6 A, *4*) and are inserted ventrally on the bases of the parameral plates; those of a second pair (*5*) arise laterally on the basal ring and are inserted mesally on the ventral ends of the parameral plates; those of the third and fourth pairs (*6, 7*) cross each other on each side, going from the dorsal wall of the basal ring to the dorsal basal margins of the parameral plates.

THE PARAMERES (*Pmr.*).—*Harpides* Audouin (1821); *cochlearia* Hartig (1837); *forceps, truelles,* or *spatules* Dufour (1841); *squamae* Thomson (1872), Schmiedeknecht (1882-'84); *valvae externae* Zander (1900); *styli* Beck (1933); *harpes* Crampton (1919); *palettes* Boulangé (1924); *parameres* Verhoeff (1893), Snodgrass (1935); *gonosquamae* Peck (1937).

The parameres of Hymenoptera, as in other insects, are the lateral branches of the primary phallic lobes. In the adult, therefore, they are hollow extensions of the distal lateral angles of the caulis (fig. 5 A, B, *Pmr*). Because the sclerotization of their outer surfaces is usually continuous with the parameral plates of the caulis, the parameres generally appear to be merely prolongations of the parameral plates, and when they are not anatomically separated from the latter the division between plate and paramere must be taken to be the base of the free lobe that constitutes the paramere. In many families throughout the Hymenoptera, however, the parameres are specifically demarked from the parameral plates by lines of flexibility or by true articular sutures, so that the parameres become flexible or freely movable appendages of the supporting plates. In such cases the joint is not always at the base of what might otherwise be called the paramere, but may be at some point distal to the latter, with the result that the caulis is produced into a pair of lateral basiparameral lobes

bearing the movable parameres (pl. 1 A, R; pl. 29 P). The articulation of the parameres on the parameral plates is a feature particularly characteristic of the chalastogastrous families other than Orussidae and Cephoidea (pl. 1 A, H, R; pl. 2 C, M; pl. 3 H, J), and is here accompanied by the presence of a pair of specific parameral muscles, a flexor and an extensor, arising on the parameral plates (pl. 2 E, *15, 16*). The parameres, however, are flexible or articulated also in various clistogastrous forms, as in some Formicoidea (pl. 11 F, M; pl. 12 E), Chrysidoidea (pl. 13 M, R), Bethyloidea (pl. 15 E), Sphecoidea (pl. 20 Q), and particularly in Apoidea (pl. 26 Q, S; pl. 27 C, H, M, T; pl. 28 J, K; pl. 30 A, B), but in these groups the writer has only rarely found specific parameral muscles (pl. 15 O, pl. 28 B), though in some cases a muscle of the aedeagus or of the volsella may encroach on the base of the paramere or arise even within the paramere. In form and relative size the parameres are highly variable, being spatulate, forcipate, branched, hooked, broad or slender, sometimes reduced to small lobes, and occasionally they are absent.

A special feature of the paremeres in certain chalastogastrous families in which these lobes are movable is the presence on the end of each paramere of an eversible membranous area (pl. 1 I, *v*) that is retractile by a muscle arising in the base of the paramere (M. *17*). Crampton (1919) refers to these membranes as "gonomaculae," or "sensory areas"; but as appears from the study of Boulangé (1924) each organ is evidently an adhesive "vacuum cup" (*ventouse*) exerting suction against an opposing surface by the contraction of its muscle. The structures are here termed *cupping disks*.

THE AEDEAGUS (*Aed*).—*Paramèse* Audouin (1821); *fourreau de la verge* Dufour (1841); *penis* Hartig (1837), Zander (1900), Crampton (1919); *gaine du penis* Boulangé (1924); *aedeagus* Beck (1933), Snodgrass (1935), Peck (1937).

The aedeagus is specifically the intromittent part of the phallic apparatus since it contains the terminus of the genital exit tract. The primary mesodorsal lobes of the phallus, in uniting to form the aedeagus, coalesce first by their dorsal margins, producing an inverted trough open below by a long median slit, and this primitive condition (fig. 5 B, G) is retained in the adult of many Hymenoptera, particularly in Chalastogastra and Ichneumonoidea. In others, however, the ventral edges of the aedeagal lobes also unite for a varying distance from their bases, thus converting the aedeagus into a tube opening by a distal slit on its ventral surface or by a terminal orifice (H, *Phtr*).

The lateral walls of the aedeagus contain a pair of elongate sclerites (fig. 5 G, *pv*), the *laminae aedeagales,* or *penis valves* (*thyrses* Audouin, 1821; *baguettes du fourreau* Dufour, 1841; *crochets* Seurat, 1899; *penisvalvae* Crampton, 1919; *valves du pénis* Boulangé, 1924). The distal ends of the aedeagal sclerites usually project more or less as a pair of free apical points or lobes, and are sometimes deeply separated by a long median cleft. Proximally the aedeagal sclerites are directly continued into the lumen of the caulis as two strong, usually divergent arms (*apa*), the *aedeagal apodemes* ("parameres" of Peck, 1937), on which are inserted most of the aedeagal muscles (fig. 6 B). At the bases of the apodemes, however, are two small lateral processes (*e*), the *ergots* of Boulangé, which also give attachment to muscles, and in some cases serve as a pair of trunnions, or points by which the aedeagus articulates on the adjoining margins of the parameral plates. The dorsal wall of the aedeagus is generally membranous and distensible, but it is sometimes weakly sclerotized, and it may contain a median rod or plate prolonged proximally into the dorsal wall of the caulis. Some of the various shapes assumed by the aedeagus will be shown in following sections of this paper. In strophandrious species the primarily ventral groove or phallotreme of the aedeagus becomes secondarily dorsal.

The usual musculature of the aedeagus, as shown by Boulangé (1924), includes five pairs of muscles (fig. 6 B). Two pairs arise ventrally on the proximal ends of the parameral plates, one (*8*) going to the apices of the aedeagal apodemes, the other (*9*) to the basal processes (ergots, *e*) of the latter. A third pair (*10*) arises dorsally on the posterior mesal parts of the parameral plates, or on the parapenial lobes of the latter when such lobes are present, and goes anteriorly to the apices of the aedeagal apodemes. Another pair (*11*) arises on the mesal dorsal margins of the parameral plates or their parapenial lobes and is inserted distally on the inner faces of the penis valves of the aedeagus. The fifth pair (*12*) arises laterally on the parameral plates and is inserted mesally on the basal processes of the aedeagal apodemes. In addition to these usual muscles of the aedeagus Boulangé reports the occurrence of a strong muscle uniting the apodemes observed in the tenthredinid *Abia* and in the bee *Anthidium.* Finally, in the Cephoidea a double series of fine transverse muscle fibers goes from the aedeagal apodemes to a median rod in the dorsal wall of the aedeagus and caulis (pl. 3 R, *14*), and in *Sphecius speciosus* among the Sphecoidea there are similar fibers inserted on the endophallus (pl. 18 O, *14a*).

The aedeagus of the Apoidea must be given special attention because in most of the bees the lateral aedeagal plates are deeply separated from the median part of the organ, so that the apoid aedeagus has typically a tripartite structure (fig. 5 I). The median lobe ("spatha" of Thomson, 1872, "uncus" of Franklin, 1912, 1913) retains the genital exit passage and the phallotreme (*Phtr*), and may therefore be termed the *penis* (*pen*); the lateral processes (*sag*) are commonly called the *sagittae* (Thomson, 1872), but there can be no question that the sagittae of the bees are the usual penis valves (H, *pv*) of other Hymenoptera. They always maintain a connection with the base of the penis, and their bases are produced into the aedeagal apodemes (*apa*) giving attachment to the same muscles that in other groups are attached on these processes. According to Zander (1900) the sagittae of *Bombus* are shown by their development to be the true aedeagal lobes of the phallus, which have united only at their bases; the penis is a median outgrowth between them containing the opening of the endophallus ("ductus ejaculatorius" of Zander). There is no possible excuse for mistaking the sagittae for volsellar lobes. Though volsellae are entirely absent in many of the bees, they are present as reduced structures in various species. The median aedeagal lobe, or penis, may be entirely membranous, and is evidently extensible by eversion of the endophallus, but it sometimes contains a dorsal sclerotization. Though the aedeagus thus becomes a relatively complex·organ in most of the Apoidea, it retains the simple generalized structure in some families, and in *Apis* it is reduced to a pair of valvelike lobes (fig. 5 J, *pv*), from between which is everted the huge endophallus (*Enph*).

THE ENDOPHALLUS (*Enph*).—The endophallus is the internal, more or less eversible sac of the phallus, receiving the ductus ejaculatorius at its anterior end, and opening distally through the phallotreme of the aedeagus (fig. 5 G, *Enph*). It is the terminal part of the definitive genital exit tract formed between the united phallic rudiments, by most writers generally regarded as a continuation of the ductus ejaculatorius. In the Hymenoptera the endophallus is variable in size; it may be a mere pocket receiving the ductus ejaculatorius, and it does not usually extend much beyond the base of the aedeagus (G, H, I). Probably it is always eversible, but it is not often found everted in museum specimens. In the genus *Apis* the endophallus attains an extraordinary size and development (J, *Enph*), accompanied by a reduction of the ectophallus, and when everted at the time of mating constitutes the functional "penis" of the bee.

THE VOLSELLAE (*Vol*).—It is difficult to give the synonymy of the volsellae because most writers have applied the term "volsella"

to one of the free volsellar lobes, or have named the lobes and the supporting plates as if they had no relation to each other. As already shown, each volsella (fig. 5 E) consists typically of a basal *lamina volsellaris* (*lv*), or *basivolsella* (Peck, 1937), and of two free distal lobes. One of the lobes is a direct continuation of the volsellar plate, and is here named the *cuspis volsellaris* (*cus*) ; the other is movable on the end of the volsellar plate, and is named the *digitus volsellaris* (*dig*). The volsellar plate is anatomically a ventral sclerite of the caulis ("pièce complémentaire" of Boulangé, 1924). The digitus and cuspis are the *copulatory ossicles* of Crampton (1919). Ontogeneti- cally the volsellar digiti represent a pair of mesoventral lobes of the caulis ("valvae internae" of Zander, 1900). Unfortunately the devel- opment of the phallus has been studied only in species in which the cuspides are very small or absent, but the cuspidal lobes would appear to be merely secondary outgrowths of the volsellar plates. It is probable that the term "volsella" (volselle or tennette of Dufour, 1841), meaning "a pair of tweezers," was first given to the copulatory ossicles to distinguish these small inner pincerlike structures from the large "outer forceps" formed by the parameres. However, inasmuch as each pair of ossicles and the supporting plate, together with their muscles, constitute a definite mechanical unit in the phallic apparatus, the writer follows Peck (1937) in applying the term *volsella* to the entire structure. The *cuspis* is the "distivolsella" of Peck; other writers have not recognized its individuality. The *digitus* is the "lacinia" of Thomson (1872), the "valva interna" of Zander (1900) in *Vespa*, the "pièce en trébuchet" of Boulangé (1924), the "gono- lacinia" of Peck (1937), the "sagitta" of Pratt (1940). In the Apoidea the term "volsella" has usually been misapplied to a lobe of the paramere, and in the Vespoidea the digitus has been mistaken for the sagitta of the aedeagus in the bees.

The volsellar plates lie in the ventral wall of the caulis along the mesal margins of the parameral plates (fig. 5 B, *lv*), from which they are usually separated by narrow lines of membrane, though some- times the volsellar plates are united with the corresponding parameral plates or completely merged into the latter. Generally a median mem- branous area of the caulis wall intervenes between the volsellar plates, but in some cases the plates are joined by a basal bridge, or may even be fully united with each other. Typically each volsellar plate is strengthened by an internal longitudinal ridge (E, *vr*), the external groove of which divides the plate into a lateral and a mesal area. If one area is desclerotized the ridge becomes marginal on the other, and the ridge persists when both areas are membranous. The anterior end

of each plate usually forms an apodemal inflection (*apv*) for the attachment of muscles. The volsellar plates either lie horizontally between the parameral plates (fig. 5 C), or they are inflected dorsally against the inner surfaces of the latter (D, E) and thus form the lateral walls of a concavity on the ventral side of the caulis. In the horizontal position the cuspis is lateral and the digitus is mesal on the end of the volsellar plate, but with the dorsal inflection of the plate (E) the digitus assumes a dorsal position relative to the cuspis. When
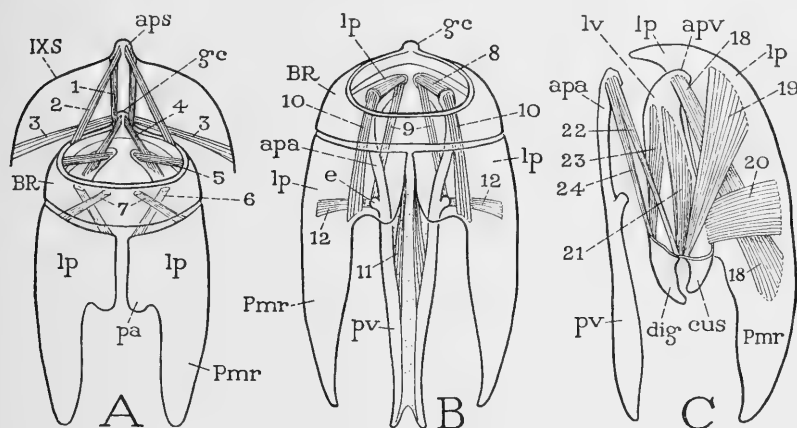
FIG. 6.—The phallic musculature, diagrammatic
(based partly on Boulangé, 1924).

A, extrinsic muscles of the phallus arising on ninth abdominal sternum, and intrinsic muscles between basal ring and parameral plates of phallus, dorsal view. B, muscles of the aedeagus, dorsal view. C, complete musculature of a volsella, dorsal view of right organ, but all muscles shown not present in any one species.

aps, basal apodeme of ninth abdominal sternum; *apv,* basal apodeme of volsellar plate; *BR,* basal ring of caulis; *cus,* cuspis of volsella; *dig,* digitus of volsella; *gc,* gonocondyle of basal ring; *lp,* lamina parameralis; *lv,* lamina volsellaris; *pa,* parapenial lobe of parameral plate; *Pmr,* paramere; *pv,* penis valve; figure 1-24, phallic muscles (see text, pages 16 to 24, for explanation).

both cuspis and digitus are present the two ossicles of each pair usually form a pair of small pincers (E, *cus, dig*), but sometimes one is much longer than the other, or one may be absent. When one lobe alone is present, or greatly exceeds the other in size, the functional lobe is generally the movable digitus (F). In strophandrious species of the Chalastogastra the volsellae are secondarily dorsal.

The volsellar musculature includes muscles that move the volsella as a whole, and muscles that move the terminal lobes—eight muscles in all, though they do not all occur in the same species. Seven of these muscles, shown diagrammatically at C of figure 6, are as follows: *18,* protractor of the volsella, arising posteriorly on the side of the para-

meral plate or in the base of the paramere, inserted anteriorly on the basal apodeme (*apv*) of the volsellar plate; *19*, retractor of the volsella, arising anteriorly on the parameral plate, inserted posteriorly on the base of the cuspis; *20*, rotator of the volsella, present in Vespoidea, arising dorsally on the side of the parameral plate, inserted ventrally on the lateral margin of the volsellar plate; *21*, intrinsic muscle of the volsella, arising anteriorly on the volsellar plate, inserted posteriorly on the base of the cuspis or between cuspis and digitus, probably closing the ossicles against each other; *22*, aedeagal flexor of the digitus, from the apex of the aedeagal apodeme (*apa*) to the outer or ventral angle of the base of the digitus (muscle *m* of Boulangé, observed only in Siricidae); *23*, volsellar extensor of the digitus, arising on the volsellar plate, inserted on the mesal or dorsal angle of the base of the digitus (muscle *s* of Boulangé, present in Tenthredinoidea, Siricidae, Cephidae, and Ichneumonidae, variable in other groups, usually absent); *24*, aedeagal extensor of the digitus, arising on the aedeagal apodeme, inserted on the mesal or dorsal angle of the base of the digitus (muscle *n* of Boulangé, present in Pamphiliidae, Siricidae, and Ichneumonidae, generally absent in other groups). An exceptional muscle, observed only in the sphecoid *Sphecius speciosus* (pl. 18 M, *25*), arising on the base of the parameral plate and inserted on the apodeme of the volsellar plate, evidently serves as a direct antagonist to the protractor of the volsella (*18*). The volsellar muscles most commonly present are *18*, *19*, and *21*. Though the digitus is always the movable unit of the volsellar pincers, it is curious that in most species there are no muscles inserted directly upon it, but it can be demonstrated in many cases that pressure on the base of the cuspis closes the two ossicles upon each other.

The strong and elaborate musculature of the volsellae indicates that these organs are important elements of the male copulatory apparatus. According to Peck (1937) specimens of the ichneumonid *Angitia fenestralis* taken *in copula* show that the pincers of the volsellae grasp the conjunctival membrane of the female in the neighborhood of the vulva, evidently keeping the membrane taut while the aedeagus is inserted. The volsellae are characteristic genital features of the Hymenoptera having in other insects no counterparts, except possibly the undifferentiated ventral lobes of the phallus in Orthoptera.

III. CHALASTOGASTRA

The comprehensive work of Boulangé (1924) on the male genitalia of the Chalastogastra not only is an exhaustive study of the genital apparatus within this group, but also it establishes a foundation for a

comparative study of the male organ in all other Hymenoptera. The general application of Boulangé's results has been discussed in the introductory parts of this paper, and nothing has been found to discredit any of his descriptions or interpretations in the Chalastogastra.

There is no feature of the male genital organ that would separate all members of the Chalastogastra from clistogastrous Hymenoptera, but the chalastogastrous families can be divided concisely into two major groups according as the parameres of the phallus are articulated on the parameral plates, or are directly continuous with the latter. The second group includes the Cephoidea and the family Orussidae; the first comprises all the other families. The articulation of the parameres in Chalastogastra is accompanied by the presence of specific parameral muscles, an extensor and a flexor for each appendage, arising on the parameral plates. These muscles are absent in Cephoidea and Orussidae, and only rarely among clistogastrous species having articulated parameres has the writer observed the occurrence of parameral muscles, as in the bethylid *Pristocera armifera,* the vespoid *Cryptocheilus unifasciatus* (pl. 15 O), and the apoid *Crocisa crucifera* (pl. 28 B).

A second feature known only among the Chalastogastra is the presence of cupping disks on the ends of the parameres. The cupping disks, however, are limited to a certain group of families among those that have articulated parameres, including the Xyelidae, Megalodontidae, Pamphiliidae, Syntectidae, Xiphydriidae, and Siricidae. They are absent in the families usually included in the Tenthredinoidea, which also have articulated parameres.

A third feature of the genital apparatus, again occurring only within the Chalastogastra, is the inversion of the phallus. The strophandrious (inverted) condition is characteristic of the Tenthredinoidea, but it is not entirely distinctive of this superfamily because it occurs also in at least two species of Xyelidae (*Xyela minor* and *Pleroneura koebelei*). Since the Xyelidae would appear in many respects to be generalized Chalastogastra, it is interesting to note that both the orthandrious and the strophandrious condition occurs among them. That the Xyelidae are not closely related to the other strophandrious families having articulated parameres is shown by their lack of a hypostomal bridge closing the back of the head.

The aedeagus of most of the Chalastogastra has the form of an inverted trough (secondarily open above in strophandrious forms) with the phallotreme at its base; in Cephoidea, however, the aedeagus is tubular and the phallotreme is apical or subapical.

The possible grouping of the chalastogastrous families on a basis of characters in the male genitalia shown above may be tabulated as follows:

I. Parameres articulated on the parameral plates and movable by special muscles, aedeagus troughlike.
    A. Cupping disks present.
        1. Head without hypostomal bridge—Xyelidae.
        2. Head with hypostomal bridge—Megalodontidae, Pamphiliidae, Syntectidae, Xiphydriidae, Siricidae.
    B. Cupping disks absent—Tenthredinoidea.
II. Parameres continuous from the parameral plates, devoid of muscles, cupping disks absent.
        1. No constriction at base of abdomen, cenchri present, aedeagus troughlike—Orussidae.
        2. Abdomen constricted between first and second segments, cenchri absent, aedeagus tubular—Cephoidea.

XYELIDAE.—*Macroxyela ferruginea* (Say) (pl. 1 A-E), *Xyelecia nearctica* Ross, *Megaxyela langstoni* Ross, *Xyela minor* Norton (pl. 1 F-M), *Pleroneura koebelei* Roh.

The abdomen of the Xyelidae has the typical tenthredinoid structure. In *Xyela minor* (pl. 1 F, G) the first abdominal tergum is divided medially and the venter of the first segment is unsclerotized. The ninth sternum forms a large, exposed subgenital plate (G, *IXS*), but the dorsum of the ninth segment is membranous except for two lateral sclerotic tergal remnants on the anterior margin (L, *IXT*), as also in *Macroxyela ferruginea* (C). The tenth segment is membranous and bears the pygostyles laterally (C, F, L, *X*).

The Xyelidae are classed by Ross (1937) with the Pamphiliidae and Megalodontidae in the superfamily Megalodontoidea, of which all the members are presumed to be orthandrious, since the Tenthredinoidea are said by Ross to be "unique in having the male genitalia inverted." The strophandrious condition, however, occurs in two of the five nearctic genera of Xyelidae given by Ross, namely *Xyela* and *Pleroneura*. The orthandrious type of phallic structure is illustrated by Crampton (1919, figs. 27, 28) in *Megaxyela aenea,* and by Ross (1937, fig. 167) in *Macroxyela ferruginea*. The phallus of these species is of simple form (pl. 1 A, B), the basal ring opens anterodorsally, the parameral plates (*lp*) form long basiparameral lobes supporting the movable parameres (*Pmr*), the aedeagus is deeply cleft between its lateral plates, and is open below (A, B, *Aed,* D). The volsellae are ventral, but are not seen unless the parameral plates are spread apart. The volsellar plates lie against the mesal faces of the

basiparameral lobes (E, *lv*) ; each plate ends in a simple cuspidal process (*cus*) and bears a movable digitus (*dig*).

The strophandrious type of phallic structure is well shown in *Xyela minor* (pl. 1 H, I). The basal ring here opens directly forward, and the usual dorsal surface of the phallus is turned downward (H). The volsellar surface (I) is therefore secondarily dorsal, and the phallotreme (*Phtr*) lies on the upper surface of the aedeagus (*Aed*). The volsellae have the usual structure (K), except that the inversion of the phallus gives the digiti a ventral position relative to the cuspides (I). Because of the anterior position of the foramen of the basal ring the phallus is easily revolved, but of many specimens examined none was found to have the phallus in other than the inverted position. The phallus of *Pleroneura koebelei* appears at first sight to be orthandrious because the parameres are turned downward, instead of upward as in *Xyela minor,* but a closer inspection shows that the aedeagus is open dorsally, and that the volsellar plates are connected with the upper edges of the parameral plates. Only one specimen of this species was available for examination.

The presence of well-developed cupping disks on the ends of the parameres in the Xyelidae (pl. 1 M, *v*) separates the members of this family from the Tenthredinoidea, and might seem to relate them to the Xiphydriidae and Siricoidea, but the Xyelidae are in many respects more generalized than the latter groups, and are readily distinguished from them by the absence of a hypostomal bridge between the foramen magnum and the base of the labium.

TENTHREDINOIDEA.—*Gilpinia polytoma* (Htg.) (pl. 1 N, P, R, S), *Neodiprion sertifer* (Geoff.) (pl. 1 O, Q), *Pteronidea ribesii* (Scop.) (pl. 2 A-I).

The general form and structure of the abdomen of *Gilpinia polytoma* is shown at N of plate 1, that of *Pteronidea ribesii* at A of plate 2. The first abdominal tergum in each species is divided medially by a triangular membranous area ; its acrotergite (*atg*) is distinct, but is not united with any part of the thorax. The dorsum of the ninth segment contains a pair of lateral tergites (pl. 1 O, P; pl. 2 B, *IXT*), but is mostly or entirely concealed beneath the eighth tergum (pls. 1 N, 2 A). The ninth sternum forms the large subgenital plate (*IXS*). The tenth segment bears laterally the pygostyles, and its dorsal surface contains a pair of weakly sclerotized tergal sclerites separated medially (pl. 1 O, P, X).

The male genital organ of the Tenthredinoidea is characterized by the articulation of the parameres on the parameral plates, the absence of cupping disks on the parameres, and the inversion of the phallus.

Crampton (1919) gives illustrations of the phallic structure in 12 species of the group, and Boulangé (1924) describes and figures species representing 22 genera. The three species here included will sufficiently show the general features of the tenthredinoid phallus.

Because of the inversion of the phallus the lower side (pl. 1 R; pl. 2 C) is the true dorsal surface, and the upper side (pls. 1 S, 2 D) the primary ventral surface. As a consequence, the foramen of the basal ring is turned anteroventrally, the volsellae appear on the upper surface, and the groove of the aedeagus containing the phallotreme (*Phtr*) at its base is exposed dorsally. The parameral plates (*lp*) are produced into thick basiparameral lobes that support the movable parameres on their distal ends. On the upper (true ventral) surface of the phallus the parameral plates are widely divergent (pl. 1 S; pl. 2 D, *lp*); on the lower surface their bases are produced mesally into a pair of parapenial lobes extending beneath the base of the aedeagus (pl. 1 R, *pa*). In *Pteronidea ribesii* the parapenial lobes (pl. 2 C, H, *pa*) project upward and are therefore seen from above (D) overlapping the mesal angles of the parameres. The parapenial lobes are morphologically dorsal, and always have this position where they occur in orthandrious species. The aedeagus is simple; its lateral plates, or penis valves (pl. 1 S; pl. 2 D, *pv*), are separate distally, membranously united proximally by their lower edges, and produced basally into a pair of slender apodemes (pl. 2 G, *apa*). The upper surface of the aedeagus presents a deep open channel, with the phallotreme (*Phtr*) in its anterior end. The volsellae are of typical structure (pl. 1 Q; pl. 2 I), though reversed in position by the inversion of the phallus. The elongate volsellar plates lie along the mesal margins of the parameral plates on the upper surface of the phallus (pl. 1 S, *lv*); in *Pteronidea ribesii* they are united with the parameral plates (pl. 2 D, *lv*). Owing to the phallic inversion, the digiti are dorsal and the cuspides ventral (pl. 2 H).

PAMPHILIIDAE.—*Acantholyda erythrocephala* (L.) (pl. 2 J-O, S).

The pamphiliids are included by Ross (1937) with the Xyelidae and Megalodontidae in a superfamily Megalodontoidea, but though they have in common with the Xyelidae (and Siricoidea) the cupping disks of the parameres, they differ from the xyelids in that the head is closed behind by a hypostomal bridge between the lower angles of the postgenae, as in the siricids. Judging from the male genitalia alone, the Pamphiliidae would appear to be more closely related to the Siricoidea than to any other superfamily of the Chalastogastra.

The dorsum of the ninth abdominal segment of *Acantholyda erythrocephala,* ordinarily concealed by retraction beneath the eighth tergum

(pl. 2 J), contains two lateral tergites (L, *IXT*). The tenth segment has a well-developed tergal plate (J, L, *XT*) with only a small membranous median area. The subgenital sternum is relatively small and simple (K, *IXS*). The phallus is not inverted (M, N). The basal ring (*BR*) is narrow above and below, the parameral plates (*lp*) lack parapenial lobes; the parameres (*Pmr*) are articulated on the parameral plates and provided distally with cupping disks (N, *v*); the aedeagus (*Aed*) is small, bifid terminally, presents a deep open groove below (N, O) with the phallotreme (*Phtr*) at its base, and has long basal apodemes (O, *apa*) continuous from its lateral plates (*pv*). The volsellae are conspicuous on the ventral side of the phallus (N), where the volsellar plates (*lv*) adjoin the mesal margins of the parameral plates (*lp*). The cuspides (*cus*) are much reduced, the digiti (*dig*) are long and curved laterally (S). The general structure of the phallus in *Acantholyda erythrocephala* shows no essential difference from that in *Pamphilius persicus* (MacG.), *Cephaleia fascipennis* (Cress.), and *Cephaleia frontalis* (Westw.) as figured by Crampton (1919), or in *Neurotoma* (*Pamphilius*) *flaviventris* Retz. as described by Boulangé (1924).

XIPHYDRIIDAE.—*Xiphydria maculata* (Say) (pl. 2 P, Q, R; pl. 3 F, J, K).

The tergal plates of the first abdominal segment are separated by a narrow median line; the ninth sternum is a fairly large subgenital plate, but the distal parts of the phallus project beyond it (pl. 2 P); the ninth and tenth terga (Q) are so nearly confluent that it is difficult to detect a separating line, but the anterior margin of tergum *IX* is definite and unbroken, as shown also by Crampton (1919) in *Xiphydria mellipes* (Say).

The phallus of *Xiphydria maculata* (pl. 3 J, K) is of generalized form and structure; the basal ring (*BR*) is narrow above and below, and opens anterodorsally; the parameral plates (*lp*) are produced into long basiparameral lobes bearing at their ends the relatively short parameres (*Pmr*), which are articulated, musculated, and provided with subapical cupping disks (*v*); the aedeagus (*Aed*) is laterally compressed, bifid distally, and presents ventrally (K) a deep open groove with the phallotreme (*Phtr*) at its base between the broad lateral plates (F, *pv*); the long volsellar plates lie against the elongate ventral margins of the parameral plates (K, *lv*), and bear each a small cuspis (*cus*) and digitus (*dig*), the latter provided with a large extensor muscle arising on the corresponding volsellar plate (pl. 2 R, *23*). The genital organ of *Xiphydria maculata* is illustrated also by Ross (1937), and closely resembles that of *X. mellipes* (Say) as

figured by Crampton (1919), and of *X. dromedarius* F. as described and illustrated by Boulangé (1924).

SIRICIDAE.—*Sirex abbottii* Kirby (pl. 3 A-E, H, I).

Boulangé (1924) in his treatment of the Siricidae includes the segmentation and musculature of the distal abdominal segments of *Sirex juvencus* L., and a full account of the structure and musculature of the copulatory organ of *Sirex juvencus* and *Xeris spectrum* L. The phallus of *Tremex columba* (L.) and of *Sirex edwardsii* Brullé is figured by Crampton (1919), and that of *Urocerus flavicornis* Fab. by Ross (1937).

In *Sirex abbottii* the ninth abdominal tergum, which is mostly concealed beneath the eighth (pl. 3 A, *IXT*), consists of two large triangular lateral plates united by a narrow sclerotic median bridge (C). The tenth tergum (A, C, *XT*), bearing the small pygostyles laterally, projects beyond the eighth, and overlaps the base of the freely protruding phallus (A, *Phl*), which is supported below on the large triangular subgenital plate formed by the elongate ninth sternum (A, B, C, *IXS*).

The phallus of *Sirex abbottii* (pl. 3 H, I) resembles that of *S. edwardsii* and *S. juvencus* described respectively by Crampton and by Boulangé. The parameral plates are contiguous dorsally (H, *lp*) beyond the broad dorsal surface of the basal ring (*BR*), but ventrally (I) they are widely separated and prolonged anteriorly into a deep emargination of the ventral surface of the basal ring. The broad articulated parameres (*Pmr*) are strongly musculated, and each bears distally a large oval cupping disk (I, *v*) provided with a wide retractor muscle arising in the base of the paramere. The aedeagus is short, deeply grooved below to the base of the free part between its lateral plates, proximal to which a slender median rod continues anteriorly in the ventral wall (E, *d*), as described by Boulangé for *Sirex juvencus*. The lateral sclerites of the aedeagus (E, *pv*) are produced proximally each into a short aedeagal apodeme (*apa*). The large volsellar plates are freely exposed on the ventral surface of the phallus (I, *lv*) between the widely separated ventral edges of the parameral plates. Each volsellar plate, as shown by Boulangé in *Sirex juvencus,* is divided by a longitudinal ridge (*vr*) into a median and a lateral part. The median part bears distally a large, freely movable, strongly toothed digitus (I, D, *dig*), the lateral part a very small cuspis (*cus*). The phallus of *Xeris spectrum* described by Boulangé would appear to be much like that of *Sirex,* but the phallus of *Tremex columba* as shown by Crampton is more elongate, and the parameral plates are divergent dorsally.

ORUSSIDAE.—*Orussus sayi* Westw. (*terminalis* Newm.) (pl. 4 D-J).

The orussids were given the status of a suborder (Idiogastra) of Hymenoptera by Rohwer and Cushman (1917) because of certain peculiar features they possess, such as characters of the wing venation and the ventral position of the antennae. The orussids, these authors say, are more nearly allied by adult characters to the siricoid families of the Chalastogastra, while on larval characters they would appear to be related to the Clistogastra. Ross (1937) places the Orussidae under the Siricoidea. On a basis of the male genitalia the orussids fall in with the Cephoidea by reason of the continuity of the parameres with the parameral plates (pl. 4 I, J); but, on the other hand, the orussid aedeagus is widely open below (J, *Aed*) and the phallotreme (*Phtr*) is basal, as in noncephoid Chalastogastra, while, furthermore, the orussids possess cenchri, which are absent in the cephoids, and they have no constriction between the first and second segments of the abdomen (F). Finally, the orussids differ from all other Chalastogastra in the lack of a median division of the first abdominal tergum, and in the separation of the metapleuron (F, Pl_3) into anterior and posterior sclerites as in Clistogastra.

The abdomen of *Orussus sayi* presents eight distinct tergal plates in the dorsum; the venter ends with the ninth sternum (pl. 4 F). The tergum of the first segment is undivided by a median suture or membranous area, and the antecostal suture behind the acrotergal area (*atg*) is scarcely perceptible, though it is marked internally by a strong transverse ridge. The metapleuron (Pl_3) is divided into a slender anterior epipleurite, and a large triangular hypopleurite, and the pleural suture is almost suppressed. The tergum of the ninth abdominal segment consists of a pair of triangular lateral tergites (G, *IXT*), between which is a single median tergal plate (*XT*) of the tenth segment, which latter bears the pygostyles (*Pgs*).

The phallus has a generalized structure, and a simplified appearance because of the shortness of the parameres (pl. 4 I, J). The basal ring (*BR*) is wide above, narrow below, and opens anterodorsally. The parameral plates (*lp*) are partly contiguous on the dorsal surface (I) and are prolonged anteriorly on the ventral surface (J). They are directly continued into the short parameres (*Pmr*). The volsellar plates (D, J, *lv*) are long, narrow, and widely separated; each is produced into a long cuspidal process (*cus*) and bears a smaller digitus (*dig*), both of which, however, project far beyond the short parameres and aedeagus. The digitus is strongly toothed at its apex (E). The aedeagal valves are widely open below (H, *pv*), separated distally by

3

a deep notch, and prolonged proximally into short aedeagal apodemes (*apa*) with prominent basal apophyses (*e*). The phallotreme (*Phtr*) lies at the base of the aedeagus, where it opens into the ventral groove of the latter.

CEPHOIDEA.—*Cephus cinctus* Nort. (pl. 3 G, L-P, T), *Cephus pygmaeus* (L.), *Janus integer* (Nort.), *Trachelus tabidus* (F.) (pl. 3 Q-S), *Hartigia trimaculata* (Say) (pl. 4 A-C). The phallus of *Cephus cinctus* is illustrated also by Crampton (1919), that of *Janus integer* by Ross (1937), and that of *Cephus pygmaeus* and of *C. pallipes* Kl. by Boulangé (1924).

The Cephoidea are set off from all other Chalastogastra by the tubular form of the aedeagus (pl. 3 T), and from all but the Orussidae by the continuity of the parameres with the parameral plates, with which feature is associated the absence of specific parameral muscles. Though Boulangé (1924) in his figures of *Cephus pygmaeus* and *C. pallipes* appears to represent the parameres ("palettes") as articulated on the parameral plates, he says (p. 214), "il faut remarquer que si la palette nous a semblé devoir être considéré comme une pièce distincte nous croyons qu'elle est plutot flexible que réellement articulée." He notes that the "palettes" are devoid of muscles. An examination of *Cephus pygmaeus* shows that the parameral lobes are conspicuously differentiated from the basiparameral regions by their bright yellow color, that they are flexible at their bases, but not truly articulated, and have no muscles. Both Crampton (1919) and Ross (1937) show the parameres of *Cephus cinctus* and of *Janus integer* continuous with the parameral plates. The parameres have no cupping disks. Another distinctive feature of the Cephoidea is the separation of the lateral tergites of the first abdominal segment by a wide, triangular, membranous dorsal area, and the constriction between the first and second segments (pl. 3 L). Cenchri are absent on the metanotum. The dorsal areas of the ninth and tenth abdominal segments are well differentiated in *Cephus cinctus* (pl. 3 M, N) and *Trachelus tabidus* (S), and each dorsum contains an undivided tergal plate. The pygostyles (N, S, *Pgs*) are borne laterally on the tenth segment.

The cephoid phallus (pl. 3 O-R; pl. 4 A, B) has a distinctive appearance because of the large size of the basal ring (*BR*), which is widely open anterodorsally. The parameral plates (*lp*), which are directly continuous with the parameres (*Pmr*), are short on the upper surface of the phallus, but greatly extended proximally on the ventral surface. The volsellar plates (*lv*) are slender and closely associated with the ventral margins of the parameral plates, from

which they may not be completely separated anteriorly. The cuspis and digitus (*cus, dig*) of each volsella are of approximately equal length, and the digitus has an extensor muscle arising on the volsellar plate (pl. 4 C, *23*). The tubular form of the cephoid aedeagus, as contrasted with the troughlike structure of the organ in other Chalastogastra, results from a membranous union of the ventral edges of its lateral plates (pl. 3 P, R, T; pl. 4 B, *Aed*). The phallotreme is therefore terminal or subterminal (pl. 3 T, *Phtr*) instead of basal. The membranous ventral wall of the aedeagus is strengthened by a long slender median rod (pl. 3 R, T, *d*), on which, as shown by Boulangé (1924, fig. 119), are inserted a double series of transverse intraaedeagal muscle fibers (R, *14*).

IV. ICHNEUMONOIDEA

Only three families of Ichneumonoidea are here discussed, namely, the Ichneumonidae, the Evaniidae, the Braconidae, and of these, principal attention is given to the last because the genital structures of the ichneumonids have been well described by Peck (1937), and their taxonomic value discussed by Pratt (1939).

ICHNEUMONIDAE.—*Megarhyssa lunator* (F.) (pl. 4 K, L, N-U), *Ichneumon irritator* F. (pl. 4 M), *Protichneumon grandis* (Brullé) (pl. 5 A-I), *Therion morio* (F.) (pl. 5 J-P), *Trogus vulpinus* (Grav.) (pl. 5 Q-W), *Megaplectes monticola* (Grav.) (pl. 5 X-Z'), *Paniscus* spp. (pl. 6 A, B), *Arotes amoenus* Cress.

The last fully exposed dorsal plate of the ichneumonid abdomen is tergum *VIII;* the tergal plates of segments *IX* and *X* are either partly exposed behind tergum *VIII,* or are entirely retracted beneath it, though the pygostyles are not completely covered (pl. 4 N; pl. 5 A, B, L, Q, X). On the venter, however, sternum *IX* is always a free subgenital plate. The tergum of segment *IX* in the ichneumonids, as shown by Peck (1937), is usually divided medially into a pair of lateral tergites (pl. 4 M, *IXT*). The ninth-segment tergites, however, are generally more or less united with the tenth tergum, the three plates, when tergum *X* is entire, forming a composite *syntergum;* but more commonly tergum *X* itself is divided into a pair of lateral tergites (M, P), in which case the combined tergites of segments *IX* and *X* form a pair of lateral *syntergites*. The division between the segmental components of the tergal plates may be partly retained, or entirely obliterated. According to Pratt (1939) in the Acoenitini and Xoridini the tenth tergum is entire, and is distinct from the lateral tergites of segment *IX*. The pygostyles are always closely associated with the

posterior margin of the tenth tergum or tergites, but they are directly attached to a post-tergal membrane (pl. 4 M, P, *Pgs*) that forms a small supra-anal fold. Between the supra-anal fold and a corresponding subanal fold of the tenth segment is an invaginated pocket, into which the rectum opens anteriorly. In the male of *Megarhyssa lunator,* as already shown (p. 12), the walls of the anal pocket bear a pair of small setigerous, cercuslike appendages, which are fully exposed when the pocket is everted (pl. 4 O, P, *Cer?*). The presence of these cercuslike appendages on the eversible anal pocket suggests that the latter represents the eleventh segment, and that the appendages are the true cerci.

The phallus of the ichneumonids needs little discussion; it has a generalized structure in which the parts are easily identified. Typical examples of the phallus are seen in *Megarhyssa lunator* (pl. 4 K, L), *Protichneumon grandis* (pl. 5 D, E), *Therion morio* (pl. 5 M, N), *Trogus vulpinus* (pl. 5 U, V), and *Megaplectes monticola* (pl. 5, Z, Z'). The parameres are simple prolongations of the parameral plates; in *Paniscus* they have an armature on their mesal surfaces (pl. 6 A, B, *p, b*), described by Townes (1938). The aedeagus is relatively small and of simple structure (pl. 4 U; pl. 5 F, I, J, W); its lateral sclerites (*pv*) are united dorsally, widely open below, more or less separated at their apices, and produced basally into a pair of long apodemes (*apa*). The phallotreme is at the proximal end of the ventral aedeagal groove (pl. 4 U; pl. 5 W, *Phtr*). The ichneumonid volsellae are well developed and show good examples of the typical volsellar structure and musculature (pl. 4 S, T; pl. 5 H). The volsellar plates are turned dorsally on the lower edges of the parameral plates, and thus lie against the mesal surfaces of the latter (pl. 4 R; pl. 5 G; pl. 6 A, *lv*). The freely articulated digitus of each volsella, therefore, arises dorsally from the distal end of the volsellar plate (pl. 4 R, S,T; pl. 5 G, H, P, Y, *dig*); it usually curves downward against or past the immovable cuspis (*cus*). In *Paniscus* (pl. 6 A), however, the cuspis (*cus*) is reflected anteriorly on the outer side of the volsellar plate, and the digitus (*dig*) turns forward to meet it. In the genera *Arotes* and *Colcocentrus* it is shown by Pratt (1939) that the cuspides ("distivolsellae") are absent, which feature, Pratt says, is characteristic of the tribe Acoenitini. The absence of the cuspides gives a suggestion of the volsellar structure of the Braconidae, but the volsellar plates of *Arotes* are turned dorsally on the lower edges of the parameral plates in typical ichneumonid fashion. The volsellar musculature is strongly developed in the Ichneumonidae (pl. 4 T; pl. 5 H), a special feature

being the presence of the digital extensor muscle (*24*) arising on the apodeme of the aedeagus.

EVANIIDAE.—*Evania punctata* Brullé (pl. 6 C-F).

The stalked abdomen of *Evania* (pl. 6 C) contains eight distinct segments (*II-IX*). A pair of large spiracles is present on the sides of tergum *VIII*, but no spiracles are to be found on the other segments. The ninth tergum consists of two lateral plates separated by a deep median notch and only narrowly united before the latter. Whether this plate is tergum *IX* alone or terga *IX* and *X* united is not evident. Beyond it is a small anal papilla, but no pygostyles. The phallus (D, E) has a complete basal ring, large simple parameres continuous from the parameral plates, a slender aedeagus, and well-developed volsellae. The elongate volsellar plates (E, *lv*) lie horizontally on the ventral side of the phallus between the parameral plates (*lp*). Each plate bears a large expanded lateral cuspidal lobe (E, F, *cus*), and a slender mesal articulated digitus (*dig*). The aedeagus (D, E, *Aed*) is slender, simple and grooved below.

BRACONIDAE.—*Helcon pedalis* Cress. (pl. 6 G-J), *Rogas terminalis* (Cress.) (pl. 6 K, L), *Spathius canadensis* (Ashm.) (pl. 6 M-O), *Atanycolus rugosiventris* (Ashm.) (pl. 6 P; pl. 7 A, B, E), *Microgaster gelechiae* Riley (pl. 6 Q; pl. 7 C, D, K), *Macrocentrus cerasivoranae* Vier. (pl. 7 F-J), *Spinaria* sp. (pl. 7 L, M, N, Q), *Phanerotoma tibialis* (Hald.) (pl. 7 O, P, R), *Chelonus sericeus* (Say) (pl. 8 A-E), *Trachypetus clavatus* Guer.

The abdomen of the Braconidae shows a tendency toward an irregularity of segmentation, accompanied by a partial or complete union of some of the anterior segmental terga and a reduction in size of the posterior terga. Thus, among the species named above, the segmentation is fairly regular in *Helcon pedalis* (pl. 6 H), *Spathius canadensis* (M), *Atanycolus rugosiventris* (P), *Microgaster gelechiae* (Q), and *Macrocentrus cerasivoranae* (pl. 7 F), but in *Spinaria* sp. (pl. 7 L) the posterior three tergal plates are much reduced and concealed beneath tergum *VI*, and in *Phanerotoma tibialis* (O, R) terga *II, III,* and *IV* are united in a long carapace, behind and below which are crowded the small tergal plates of the following segments, while in *Chelonus sericeus* (pl. 8 A, B) the completely fused terga of segments *II, III,* and *IV* almost encapsulate the rest of the abdomen. The tergum of the genital segment, designated "*IXT*" on the figures, is perhaps, by comparison with the Ichneumonidae, to be regarded as the united tergal plates of segments *IX* and *X*, but no evidence of such a composition was observed specifically in the Braconidae. Otherwise, the tenth segment consists of the anal region, which bears laterally a

pair of small pygostyles (pl. 7 G; pl. 8 C, *X*). The exposed subgenital plate is usually sternum *IX*.

The braconid phallus, as illustrated in the species here studied, has a distinctive feature in the character of the volsellae. The volsellar plates, instead of being folded dorsally against the mesal surfaces of the parameral plates, as in Ichneumonidae, lie in a horizontal plane between the parameral plates, with their edges approximated beneath the base of the aedeagus (pl. 6 J, L, O; pl. 7 D, P, Q; pl. 8 E, *lv*). In some cases each volsellar plate is marked by a strong median ridge (pl. 6 O; pl. 7 D; pl. 8 E, *vr*), and if the plate becomes membranous the ridge alone remains (pl. 7 B, *lv*), giving support to the digitus, and attachment to the volsellar muscles. The volsellar cuspides are either suppressed or are represented by small lateral extensions of the volsellar plates (pl. 6 L, N, *cus*). The digiti, on the other hand, are strongly developed, freely articulated lobes, usually toothed or hooked at their apices, and turn laterally and dorsally on the ends of the volsellar plates (pl. 6 J, L, N, O; pl. 7 A, B, D, J, N, P, Q; pl. 8 D, E, *dig*). The function of the volsellae in the Braconidae thus depends on the action of the digital lobes alone. It is interesting to note that a similar condition recurs in the Chalcidoidea and Cynipoidea. The braconid aedeagus is of simple structure, broad or slender, notched at the apex, grooved below (pl. 6 I-L, N, O; pl. 7 A-D, H-J, N, P, Q; pl. 8 D, E, *Aed*).

V. CHALCIDOIDEA

Berecyntus bakeri How. (pl. 8 F-H), *Callimome* sp. (pl. 8 I-K), *Callimome sackeni* (Ashm.) (pl. 8 L), *Tetrasticus bruchophagi* Gah. (pl. 8 M, P), *Pteromalus puparum* (L.) (pl. 8 N, O), *Leucospis affinis* (Say), (pl. 8 Q-T), *Ormyrus* sp. (pl. 9 A, B, D), *Brachymeria ovata* (Say) (pl. 9 C, E), *Cheiropachus colon* (L.) (pl. 9 F, G).

The chalcidoid abdomen is variable in form and in the relative size of its segments, as shown in *Berecyntus bakeri* (pl. 8 G), *Callimome* sp. (I), *Pteromalus puparum* (N), *Tetrasticus bruchophagi* (P), *Leucospis affinis* (Q, R), *Ormyrus* sp. (pl. 9 A), and *Brachymeria ovata* (C). In *Leucospis affinis* (pl. 8 Q, R) terga *V-VIII* are united. There are only two pairs of abdominal spiracles, the first on the propodium (pl. 8 F, *ISp*), the other on segment *VIII* of the "postabdomen" (I, Q, *VIII Sp*). The petiole segment (*II*) is always small, and may be reduced to a narrow ring (F, *II*) concealed between the propodium (*I*) and segment *III*. Posteriorly the abdomen usually ends with the tergal and sternal plates of segment *IX* (pl. 8 I, Q;

pl. 9 C), though the ninth sternum is sometimes concealed (pl. 8 G). Since the small setigerous pygostyles are borne on the apparent ninth tergum (pl. 8 I, J, *Pgs*), it is to be presumed that this tergal plate represents terga *IX* and *X* united.

The phallus of the chalcidoids has a characteristic elongate, compact form owing to the close union of all its parts and the reduction of the parameres (pl. 8 H, K, L, M, O, S, T; pl. 9 B, E, F, G). The wider basal part of the organ, or caulis, is composed of the elongate parameral plates and the volsellar plates though the latter are seldom distinct sclerites; a basal ring is usually not evident, though it is present in some species (pl. 8 L, T, *BR*). The narrower distal lobe of the phallus is the aedeagus (*Aed*), and from its base there extends proximally into the caulis a pair of long slender aedeagal apodemes (pl. 8 H, K, M; pl. 9 B, E, F, *apa*). At the distal end of the caulis the parameres usually are evident as a pair of small lateral lobes (pl. 8 K, L, M, T; pl. 9 B, E, F, G, *Pmr*), but they may be so reduced as to be practically absent (pl. 8 G, H). Between the parameres, below the base of the aedeagus, is a pair of conspicuous volsellar lobes, which, being movable, are probably the digiti (pl. 8 H, K, L, M, O; pl. 9 B, E, G, *dig*). They are very similar to the digital lobes of Braconidae, being characteristically turned outward from the ends of the volsellar plates, and are armed distally with strong spines. The phallus in some species is relatively large and projects far from the end of the abdomen (pl. 8 G, I), but ordinarily it is either entirely concealed, or only its distal part is exposed. In *Berecyntus bakeri* the aedeagus is armed ventrally with a pair of small hooks (pl. 8 G, H, *h*).

VI. CYNIPOIDEA

Ibalia maculipennis Hald. (pl. 9 H-L), *Diplolepis multispinosus* Gill (pl. 9 M, N, O), *Figites quinquelineata* Say (pl. 9 P, Q, R). These three species represent the families Ibaliidae, Cynipidae, and Figitidae, respectively.

The exposed abdominal segments are of approximately equal length in *Ibalia* (pl. 9 H), except the peduncular segment (*II*), which is a short, slender stalk supporting the rest of the abdomen. The eighth segment forms the rounded end of the body, and bears laterally the only pair of spiracles present on the "postabdomen" in the cynipids, as in the chalcids. The ninth tergum is small (I, *IXT*), and only its apex is exposed beyond the eighth (H). Pygostyles are absent. The slender ninth sternum (I, *IXS*) is entirely concealed above sternum *VIII*. In *Diplolepis multispinosus* (O) segment *III*, or particularly

its tergal plate, is greatly enlarged and constitutes nearly one-half of the ovate abdomen. The peduncular segment (*II*) is short, the eighth tergum (*VIIIT*) bears the spiracles, the ninth tergum (*IXT*) is partly exposed beyond the eighth. In *Figites quinquelineata* (R) segment *IV* forms the greater part of the abdomen, and the extended ventro-lateral parts of its tergal plate overlap each other beneath the sternum. The peduncular segment (*II*) is very small in this species and is completely concealed normally within the projecting anterior margin of segment *III,* but it is a complete segmental annulus connecting the "postabdomen" with the propodeum, and must be included in the enumeration of the segments.

The cynipoid phallus is characterized by the union of the volsellar plates with the parameral plates, and by the presence of only one pair of volsellar lobes, which resemble those of the Chalcidoidea, and are evidently the digiti. The phallic structure is comparatively generalized in *Ibalia maculipennis* (pl. 9 K, L,), in which species the parameres (*Pmr*) are of usual form, and the volsellar plates (L, *lv*) are partially demarked from the parameral plates (*lp*). In *Diplolepis multispinosus* and *Figites quinquelineata* the parameral and volsellar plates are entirely confluent on each side (M) ; the parameres are slender in both species, short in the second (Q). The aedeagus is simple in form, variable in length according to the length of the parameres, but in the three species illustrated it is somewhat longer than the parameres (K, L, M, *Aed*). The volsellar digiti are small, flattened; movable lobes arising from the ends of the volsellar plate areas (K, M, Q, *dig*), and are turned upward from the latter (J, N, P) at the base of the aedeagus (K). Each digitus is toothed on its dorsal margin, and is provided with a flexor muscle (J, P, *mcl*) arising anteriorly on the region of the united parameral and volsellar plates.

VII. SERPHOIDEA

Loboscelidia defecta Kief. (pl. 10 A, B), *Serphus florissantensis* Roh. (pl. 10 C-G), *Pelecinus polyturator* (Dru.) (pl. 10 H-L), *Ashmeadopria* sp. (pl. 10 M), *Trichopria cubensis* Fouts (pl. 10 N), *Galesus manilae* Ashm. (pl. 10 O, P), *Scelio calopteni* Riley (pl. 10 Q, R), *Sparasion pilosum* Ashm. (pl. 10 S).

The serphoid abdomen is highly variable in shape and segmentation. A relatively simple type of structure is seen in *Pelecinus polyturator* (pl. 10 H), in which the segments are distinct and not unusually different in size. The last exposed segmental plates are tergum *VIII* above and sternum *IX* below, but tergum *IX* is a well-developed plate

(I, *IXT*) concealed beneath tergum *VIII*, and beyond it is a small anal segment (*X*), without pygostyles. Sternum *IX* is closely connected with sternum *VIII*, and bears a long median apodeme (I, *aps*). In *Serphus florissantensis* (C) the abdomen has a large anterior dorsal plate evidently composed of three united terga (*II, III, IV*) ; behind this are four free tergal plates, of which the last is clearly tergum *VIII*, since there is concealed beneath it the usual complex of tergum *IX* and segment *X*, the latter bearing a pair of small setigerous pygostyles. The long anterior ventral plate appears to include sterna *II, III, IV*, and *V;* the subgenital plate is sternum *VIII*. In the pear-shaped abdomen of *Galesus manilae* (O) segment *II* forms the peduncle, the tergum of segment *III* covers the rest of the dorsum ; on the venter, sternum *III* is the principal plate, but is followed by a series of narrow sclerites representing sterna *IV* to *IX*. The abdomen of *Scelio calopteni* (Q) has a regular segmentation, ending at the apex with tergum *IX* above and sternum *VIII* below, sternum *IX* being a small plate concealed above sternum *VIII*.

The phallus of the serphoids attains the highest degree of modification and specialization to be found in all the Hymenoptera. A progressive union takes place between the aedeagus and the volsellae, which, accompanied finally by an elimination of the parameres, converts the phallus into a single, two-segmented shaft composed of the basal ring of the caulis, and of the united aedeagus and volsellae. A simple generalized phallic structure occurs in *Loboscelidia defecta* (pl. 10 A). Here the volsellar plates (*lv*) lie between the parameral plates (*lp*), and each is produced into two free lobes (B). It is difficult to identify the volsellar lobes, but the short median one (*dig*) may be regarded as the digitus, and the longer, lateral one (*cus*) as the cuspis. The aedeagus is entirely free from the volsellae, and its lateral sclerites end in two free points (A, *Aed*). In *Serphus florissantensis* the phallus is elongate and slender (F, G) ; on its ventral surface (G) are plainly exposed the long median volsellar plates (*lv*), each bearing a single terminal lobe (*dig*), which, being freely articulated on the supporting plate, is probably the digitus. The slender aedeagus projects from between the volsellar plates (G, *Aed*), but dissection reveals that the distal ends of the latter are united with it (E). The small, upturned digiti (*dig*), therefore, closely embrace the free distal part of the aedeagus. Proximally the aedeagus has a pair of large divergent lateral apodemes (E, *apa*), and its dorsal wall contains a slender median rod (*c*).

The association of the volsellae with the aedeagus is carried much farther in *Pelecinus polyturator,* in which the volsellar plates (pl. 10 L,

lv) are united with the entire ventral surface of the aedeagus, though they retain narrow basal connections with the parameral plates (*lp*). As a result, the aedeagus and the volsellae together form a thick median shaft of the phallus, on the dorsal surface of which are the long, slender aedeagal sclerites (J, K, *pv*) terminating proximally in the aedeagal apodemes (J, *apa*), and on the ventral surface the volsellar plates (J, L, *lv*) bearing distally the toothed digiti (*dig*) turned upward at the base of the free terminal part of the aedeagus.

In the family Diapriidae the aedeagal and volsellar elements of the phallus have become so thoroughly unified, as shown in *Ashmeadopria* sp. (pl. 10 M) and in *Trichopria cubensis* (N), that they have almost lost their identities in the median aedeago-volsellar shaft (*A-V*) of the genital organ. The aedeagal apodemes (*apa*), however, project from the base of the shaft, the free part of the aedeagus forms a terminal median lobe (*Aed*), and at the base of the latter are attached ventrally the volsellar digiti (*dig*). The individuality of the aedeago-volsellar shaft is still further accentuated by the deep separation of the parameres (*Pmr*), which are split off from the median parts almost to the basal ring. An extreme condition of the phallic modification in the Diapriidae is found in the genus *Galesus,* here illustrated in *G. manilae* (pl. 10 P). The phallus, which is retracted far into the abdomen, consists of three long, slender, curved rods arising from a small common base. The median rod (*Aed*) must be the aedeagus at least, no volsellar elements being evident in its composition; the lateral rods are the parameres (*Pmrs*).

Finally, in the family Scelionidae, the last stage in the evolution of the serphoid phallus is reached, in which the genital organ is further simplified by the elimination of the parameres (pl. 10 R, S). The phallus thus comes to consist of a proximal segment formed of the long basal ring (*BR*), and of a distal segment, which is the aedeago-volsellar shaft (*A-V*). The latter bears the volsellar digiti (*dig*) on its ventral surface, and ends with the free apical lobe of the aedeagus (*Aed*). Other genera having this same type of phallic structure, including *Microphanurus, Telenomus,* and *Nardo,* are illustrated by Nixon (1936, 1937, 1938).

VIII. FORMICOIDEA

DORYLIDAE—*Eciton coecum* (Latr.) (pl. 12 A-G) ; PONERIDAE—*Paraponera clavata* (F.) (pl. 12 H-O) ; PSEUDOMYRMIDAE—*Pseudomyrma gracilis* (F.) (pl. 13 D-I) ; MYRMICIDAE—*Pogonomyrmex barbatus* (F. Sm.) (pl. 12 P-S; pl. 13 A-C) ; DOLICHODERIDAE—

Liometopum sp. (pl. 11 H-O) ; FORMICIDAE—*Formica* sp. (*fusca* group) (pl. 11 A-G).

The last exposed segmental plates of the abdomen of male ants are tergum *VIII* and sternum *IX* (pl. 11 A, I; pl. 12 A, I, P; pl. 13 D), but the membranous tenth segment may project beyond the eighth tergum. Tergum *IX* is always concealed. It may be a transverse plate in the dorsum at the base of the tenth segment (pl. 12 H), but generally it is much constricted medially (pl. 12 Q), or separated into a pair of lateral sclerites (pl. 11 D, J ; pl. 13 F). The tenth segment is always membranous, and usually bears a pair of pygostyles at the sides of the anus (pl. 11 D, J ; pl. 12 H, Q; pl. 13 F), but in *Eciton* (pl. 12 B) pygostyles are absent. The functional anal aperture (*An*) leads into a small anal vestibule (pl. 11 D, *anv*), within which the rectum (*Rect*) opens anteriorly. Sternum *VIII* is never entirely concealed, and it undergoes relatively little modification in form (pl. 12 C, J, R ; pl. 13 E) ; sternum *IX* is more variable in shape, though usually conservative (pl. 11 E, K ; pl. 12 G, K, S ; pl. 13 E).

The phallus of Formicoidea is relatively large and protrudes at the end of the abdomen between the eighth tergum and the ninth sternum. In the Dolichoderidae it attains an extraordinary size (pl. 11 I, *Phl*) ; structurally its greatest modifications occur in the Dorylidae (pl. 12 D). A generalized condition of the organ is shown in *Formica* (pl. 11 F, G), in which all the usual phallic parts are present in relatively simple form. The aedeagus (*Aed*) appears to be slender in dorsal or ventral view ; from the side (C) it is seen that its lateral plates (*pv*) are broad dorsoventrally, and serrated on their lower margins. Each volsella (B) has large digital and cuspidal lobes, the cuspis (*cus*) being a direct continuation of the volsellar plate (*lv*), while the long base of the digitus (*dig*) is hinged to the dorsal margin of the plate.

The huge phallus of *Liometopum* sp. (pl. 11 I, *Phl*) shows no unusual feature other than that of size, its form being simple when seen from above or below (M, N). The aedeagus (*Aed*) is relatively short, but exceptionally deep in a vertical plane (H). The volsellae are mostly concealed from below by ventral lobes of the parameral plates (N, *o*), but they have the usual position against the inner faces of the basiparameral lobes (L). The slender basal plate of each organ (O, *lv*), terminating in a small cuspis (*cus*), lies horizontally and only its inner edge is visible in a direct mesal view (L) ; the large dorsal plate seen in this figure (L) is the base of the digitus (*dig*).

The unusual appearance of the phallus in *Eciton coecum* (pl. 12 D) results from the large size of the cup-shaped basal ring (*BR*), the

partial invagination of the parameral plates (*lp*) into the basal ring, and the form of the broadly expanded, petiolate parameres (*Pmr*). Both the aedeagus (F) and the volsellar digiti (E, *dig*), however, are also exceptional in shape. The volsellar plates are small and have no cuspidal lobes (E, *lv*), but the digiti are long, slender arms (D, E, *dig*), each with a large dorsal branch near its distal end.

In *Paraponera clavata* (pl. 12 L, M), *Pogonomyrmex barbatus* (pl. 13 A), and *Pseudomyrma gracilis* (pl. 13 H, I), the phallus presents no striking features, though the parameres, the aedeagus, and the volsellae have distinctive characters. The volsellae of the first species are of typical structure (pl. 12 N), and are freely exposed between the aedeagus and the parameres (L, M). In the second species volsellar cuspides appear to be absent (pl. 13 B), each volsellar plate (*lv*) bearing only a large hooked digitus (*dig*) lying against the inner face of the corresponding paramere (*Pmr*). In *Pseudomyrma gracilis* the volsellae are greatly reduced (pl. 13 G), the basal plate of each organ being a slender sclerite (*lv*) attached to the lower margin of the corresponding parameral plate (*lp*), bearing only a single, small, setigerous lobe, the digitus (*dig*).

IX. CHRYSIDOIDEA

Chrysis kansensis Vier. (pl. 13 J-N), *Chrysis conica* Brullé (pl. 13 O), *Parnopes edwardsii* (Cress.) (pl. 13 P, R), *Holopyga ventralis* (Say) (pl. 13 Q).

The abdomen of the chrysidoids consists of an anterior visceral region composed of three, four, or sometimes five segments (pl. 13 J, L), and of a concealed genital cone including the other segments and containing the phallus. The exposed tergal plates have ventral flaps, or laterotergites (L, *ltg*), which, except the first, bear the spiracles. The first sternal plate (L, *IIS*) is divided transversely, but the two parts do not represent two segments. The genital cone contains five or six segments, according as there are four or three exposed segments in the visceral region. The tenth segment is much reduced and lacks pygostyles.

The phallus of the chrysidoid species above listed has a simple form, but presents the unusual feature of having the parameral plates completely united on the dorsal surface of the caulis (pl. 13 M, R, *lp, lp*). The slender parameres (*Pmr*), therefore, are articulated on the lateral angles of a common parameral plate. The aedeagus of *Chrysis kansensis* (M, *Aed*), *C. conica* (O), and *Holopyga ventralis* is elongate, deeply cleft distally, and bears proximally a pair of short apodemes

(O, *apa*) and prominent basal processes (*e*). In *Parnopes edwardsii*, on the other hand, the aedeagus is short and broad (P, R). The volsellae of *Chrysis* and *Holopya* consist principally of two pairs of elongate lobes lying at the sides of the aedeagus (M). The larger lobe of each pair (N, Q, *cus*), being continuous from the small volsellar plate (*lv*), is evidently the cuspis; the slenderer, articulated lobe (*dig*) is hence the digitus, but in *Holopyga* (Q) it overlaps the base of the cuspidal lobe and has a lateral position. In *Parnopes edwardsii* the volsellae are reduced to a single pair of small weak lobes projecting beneath the base of the broad aedeagus.

X. MUTILLOIDEA

Dasymutilla sp. (pl. 14 A-F), *Scolia nobilitata* F. (pl. 14 G-L), *Myzine quinquecincta* (F.) (pl. 14 M-S). These three species, representing the families Mutillidae, Scoliidae, and Typhiidae, respectively, are described separately because they have in common no genital features that are characteristic of the superfamily.

Dasymutilla sp.—The abdomen (pl. 14 A) is strongly constricted between segments *II* and *III*, and terminates with tergum *VIII* above and sternum *IX* below. Sternum *IX* (B) is of simple form and bears a long median anterior apodeme (*aps*). The concealed dorsum of segment *IX* contains two lateral tergal plates (B, *IXT*) separated on the back by a membranous area, which is continuous posteriorly with the small membranous anal cone of the tenth segment (*X*). At the sides of the anal cone, behind the lateral parts of the ninth tergal plates, are two small sclerites bearing a pair of long, densely setose appendages (*Pgs*). The appendages are evidently the pygostyles since their supporting sclerites are attached to the sides of the anal cone and are prolonged anteriorly in the dorsal wall of the genital chamber. The phallus of *Dasymutilla* (D, E) is slender; the basal ring (*BR*) is elongate, the parameres (*Pmr*) long and tapering, and the parameral plates (*lp*) have dorsal parapenial lobes (D, *pa*) and shorter ventral lobes (E, *o*) concealing the base of the aedeagus (*Aed*). The short aedeagus has deep lateral plates (C) ending in decurved points, between which is a median lobe bearing the phallotreme. The volsellae consist principally of the slender digital and cuspidal lobes seen projecting between the parameres beyond the end of the short aedeagus (D, E, *dig*, *cus*). The basal plate of each organ (F, *lv*) is little more than the base of the cuspis (*cus*) attached distally to the lower margin of the corresponding parameral plate (*lv*), and giving insertion to a large muscle (*19*) arising proximally on the parameral plate. The rodlike digitus (*dig*) is attached mesally on the volsellar plate.

Scolia nobilitata F.—In this species the apex of the abdomen (pl. 14 G) is formed by tergum *VIII* above and sternum *VIII* below, the small three-pronged ninth sternum (G, H, *IXS*) being almost entirely concealed by retraction above the eighth. The tergum of segment *IX* is a transverse dorsal plate (H, *IXT*) at the base of the small anal tube of segment *X*. Pygostyles are absent. The phallus (*Phl*) is protractile on an ample basal membrane. The form of the phallus (J, K) is quite different from that in *Dasymutilla,* the parameres (*Pmr*) being relatively short and broad, parapenial lobes absent, and the aedeagus longer. The lateral plates of the aedeagus are strongly serrate below (I, *pv*) and enclose between them a deep ventral groove, at the base of which is the phallotreme (*Phtr*). The volsellae are of particular interest. Each volsella consists of a single large, strongly musculated lobe (L, *cus*), the base of which clearly represents the volsellar plate (*lv*) because it contains a small intrinsic muscle (*21*). The free part of the lobe is therefore the cuspis, and the digitus is absent. Except for the absence of the digitus, the volsella of *Scolia* thus has the same character as that of *Dasymutilla* (F).

Myzine quinquecincta (F.).—The ninth abdominal sternum of this species (pl. 14 M, *IXS*) is mostly exposed, since its distal part, proceeding from a small, concealed basal plate (O), consists of a long tapering spine curving upward behind the apex of the abdomen formed by tergum *VIII*. The concealed ninth tergum (N) is a small triangular plate with a pair of basal arms. Projecting from beneath its posterior margin are seen the small pygostyles of the tenth segment. The form and structure of the phallus are shown at P, Q, and S. The parameral plates (P, Q, *lp*) are so deeply separated from the long slender aedeagus (*Aed*) that their distal parts form a pair of independent basiparameral lobes. The elongate parameres (*Pmr*) are produced distally from the ventral angles of the parameral plates (Q, S), and the broad cuspidal lobes of the volsellae (S, *cus*) project at the sides of the aedeagus above the parameres. The volsellae are of more typical structure in *Myzine* than in either *Dasymutilla* or *Scolia*. Each has a broad basal plate (R, *lv*) produced distally into a large cuspidal lobe (*cus*), and armed on its mesal surface with a close series of strongly sclerotized, fine-toothed ridges. The digitus (*dig*) is articulated dorsally on the volsellar plate, and bears on its ventral margin a row of strong spines.

XI. BETHYLOIDEA

Pristocera armifera (Say) (pl. 15 A-D), *Goniozus hortorum* Brues (pl. 15 E, F), an unidentified gonotopodine male (pl. 15 G). These

species show the principal types of phallic structure found in the super-family, but the genitalia of a much larger series of species are illustrated by Richards (1939).

The exposed part of the bethylid abdomen usually ends with the tergal and sternal plates of segment *VIII,* the ninth sternum being generally small, concealed above the eighth, and closely associated with the under side of the phallus. In *Pristocera armifera* (pl. 15 A), however, sternum *IX* is well exposed behind sternum *VIII.* Pygostyles are absent in the species examined.

The phallus of *Pristocera armifera* (pl. 15 B, C) is not in all respects typical of the phallic organ of other bethylid species. The basal ring *(BR)* is extremely narrow, the parameral plates are much reduced on the dorsal surface (B, *lp*), and the apparent volsellar plates are united with their ventral mesal margins (C, *lv*). The parameres are movable lobes *(Pmr)*, each provided with a muscle from the corresponding parameral plate inserted on the mesal angle of its base. The broad aedeagus *(Aed)* is set deeply into the emargination between the parameral plates. The volsellar lobes are of particular interest because the immovable lobe, continuous from the volsellar plate, is mesal in position (B, C, *cus*), and the movable lobe *(dig)* is lateral. The insertion of the volsellar muscles on the mesal lobe (D, *cus*), however, leaves little doubt that this lobe is the cuspis, and that the movable lateral lobe *(dig)* is the digitus, since this is the usual insertion of the volsellar muscles, but the reversed position of the two lobes is difficult to explain.

Most bethyloid species have a well-developed basal ring in the phallus (pl. 15 E, F, G, *BR*), and large volsellar plates (F, G, *lv*) overlapped by the ventral edges of the parameral plates *(lp)*, and usually divided each by a prominent volsellar ridge (G, *vr*) into lateral and mesal areas. In *Goniozus hortorum* (E, F) each volsellar plate bears two terminal lobes *(cus, dig)*, of which, by comparison with *Pristocera armifera* (D), the inner would appear to be the cuspis, and the outer the digitus. Several species of bethylids illustrated by Richards (1939, figs. 32, 37, 84) are shown to have two distinct volsellar lobes on each side, and in such cases it is the lateral lobe that is articulated on the volsellar plate.

The most common type of volsellar structure in the Bethylidae is here illustrated in an unidentified gonotopodine male (pl. 15 G). The large volsellar plates *(lv)* are entirely free from the parameral plates *(lp)*, which normally are closer together and overlap a greater area of the volsellar plates than shown in the figure. Each volsellar plate has a strong, obliquely longitudinal volsellar ridge *(vr)*, and bears a

single terminal lobe (*dig*), which is freely movable on the plate, and is hence identified as the digitus, though in species having also an immovable lobe the latter projects from the mesal part of the volsellar plate. Further examples of this type of phallic structure are shown by Richards (1939, figs. 41, 47, 53, 57, 60, 66, 72, 75, 82, 90).

XII. VESPOIDEA

Cryptocheilus unifasciatus (Say) (pl. 15 H-Q), *Monobia quadridens* (L.) (pl. 16 A-D), *Odynerus* sp. (pl. 16 E-H), *Polistes canadensis annularis* (L.) (pl. 16 I-P), *Vespula maculata* (L.) (pl. 17 A-H), *Vespa crabro* L. (pl. 17 I-Q; pl. 18 A-D).

The exposed part of the male abdomen in Vespoidea ends with tergum *VIII* above and sternum *IX* below (pl. 15 H; pl. 16 E, I; pl. 17 A), but sternum *VIII* is never visible externally, so the venter of the "postabdomen" appears to have only seven sternal plates corresponding (deceptively) with the seven exposed tergal plates of the dorsum. Sternum *VIII* is much reduced in size and is concealed above sternum *VII* (pl. 15 J) at the base of sternum *IX,* with which it is either closely connected by membrane (pl. 16 P) or firmly united (pl. 16 C, F; pl. 17 B, C, I, L). Sternum *IX* is variable in shape, but it always has a prominent median basal apodeme (pl. 15 K, *aps*), which projects forward above sternum *VIII* regardless of the connection of the latter with sternum *IX* (pl. 16 C, F, P; pl. 17 B, C, I, L). The intimate association of the reduced and concealed eighth abdominal sternum with the base of the ninth sternum is a characteristic feature of the Vespoidea, but it occurs also in the genus *Apis* of the Apoidea (pl. 33 C, D), though in *Apis* the ninth sternum has no basal apodeme. Tergum *IX* of the vespoid abdomen is represented only by a pair of lateral sclerites in the dorsal wall of the genito-anal chamber (pl. 17 B, I, J, K, *IXT*), which connect proximally with the basal angles of sternum *IX* (B, I), and may extend distally into the dorsal wall of the proctiger at the base of the free anal lobe (B, J, *IXT*). A pair of small pygostyles is present in *Cryptocheilus unifasciatus* at the sides of the anus.

The phallus of the Vespoidea is highly variable in structure, but appears to have no feature distinctive of the group, though in the Vespidae the volsellae attain a type of structure characteristic of this family. The following examples will illustrate the structural variations and specializations of the vespoid phallus.

Cryptocheilus unifasciatus (Say).—The phallus seen from above (pl. 15 I) presents a long basal ring (*BR*), a pair of parameral plates

(*lp*) extended distally into long parapenial lobes (*pa*), lateral para-
meres (*Pmr*) articulated on the parameral plates, a median bilobed
aedeagus (*Aed*), and two mostly concealed volsellar lobes (*dig*).
These same parts are shown laterally at N, and are more clearly seen
when spread out in ventral view as at L (basal ring omitted). The
parameres are not only movably articulated on the parameral plates,
but each is provided with a muscle (O). The long slender aedeagus
(M) has a pair of divergent basal apodemes (*apa*), and its lateral
plates (*pv*) project distally as two long, free spatulate arms. The vol-
sellae are strongly developed (P, Q) ; each consists of an irregular
basal plate (*lv*) attached to the mesal ventral margin of the corre-
sponding parameral plate (L), and of a large quadrate digital lobe
(*dig*). The volsellar digiti project between the aedeagus and the
parameres (L, *dig*), though they are mostly concealed from above (I)
by the long parapenial lobes (*pa*) of the parameral plates.

Monobia quadridens (L.).—The phallus is elongate and cylindrical
(pl. 16 A, B). The lengthened parameral plates (*lp*) are continued
into short parameral lobes (*Pmr*), but each bears mesad of the para-
mere on the dorsal side a long, tapering, spinelike process (*f*), which
might be regarded as a modified parapenial lobe, more typically repre-
sented in *Cryptocheilus* (pl. 15 I, *pa*), though it can hardly be taken
for the paramere. This same parameral spine recurs in *Odynerus,
Polistes,* and *Vespa.* The slender aedeagus of *Monobia* (pl. 16 A, D,
Aed) has the usual basal apodemes (D, *apa*), but from its dorsal sur-
face a long, tapering arm (*c*) extends proximally in the membrane
uniting the upper parts of the parameral plates. The phallotreme is at
the base of a long groove on the ventral side of the aedeagus (D,
Phtr). The volsellae are well developed; the volsellar plates appear
as mesoventral lobes of the parameral plates (B, *lv*), the cuspides are
small, scalelike processes (A, *cus*), but the digiti are long lobes (*dig*)
loosely articulated on the volsellar plates, diverging distally, and bear-
ing each a broad fringe of bristles on its mesal margin.

Odynerus sp.—The phallus of *Odynerus* (pl. 16 H) more closely
resembles the phallus of *Monobia* (A, B) than that of typical vespoids
such as *Polistes* and *Vespa.* The parameres (*Pmr*) are relatively short
prolongations of the parameral plates, and the parameral spines (*f*),
arising mesad of the parameral bases, are long and slender. The vol-
sellar plates are prominent ventral sclerites of the caulis (*lv*) flanking
the base of the aedeagus; the cuspides are inconspicuous, the digiti
(*dig*) are large, pincerlike lobes crossed above the aedeagus. The
aedeagus (G) is narrowly spatulate, and has a median, tapering, basal

4

arm (*c*) prolonged from the dorsal surface between the lateral apo-
demes (*apa*).

Polistes canadensis annularis (L.).—The phallus of the Vespidae
is a thick and strongly sclerotized organ having a truncate appearance
because of the shortness of the parameres (pl. 17 D, E). It is char-
acterized by a special development of the volsellae, particularly of the
digital lobes, which latter various writers have mistaken for homo-
logs of the aedeagal sagittae of the bees.

The phallus of *Polistes* (pl. 16 K) is in some respects more general-
ized than that of *Vespa,* but it has the vespid characteristics. The
parameres (*Pmr*) are relatively broad lobes directly continuous from
the parameral plates (*lp*), and the parameral spines (*f*) arise dorsally
from the mesal margins of the parameral plates (J, L) at the bases
of the parameres. The slender aedeagus (M) has the usual basal apo-
demes (*apa*) and a long median dorsal arm (*c*). The volsellae lie
against the inner surfaces of the parameres, the volsellar plates (L,
lv) forming the mesal walls of the basiparameral lobes. Each volsellar
plate is triangular in form (O) with a long ventral base separated
by a narrow membranous area from the lower edge of the correspond-
ing parameral plate (L). The distal angle of the volsellar plate repre-
sents the cuspis (L, O, *cus*) ; the anterior angle forms the usual vol-
sellar apodeme (*apv*). A special feature of the volsellar plate, how-
ever, is the presence on the dorsal angle of a short, thick apodemal
process (J, O, *g*) directed mesally and downward. The digitus is a
large, flat, elongate lobe (J, L, *dig*) attached to the dorsal part of the
volsellar plate by two basal rami (J, N), one ramus mesal (*mr*), the
other lateral (*lr*). The mesal ramus articulates on the upper margin of
the volsellar plate (N, O, indicated by arrows) ; the lateral ramus lies
above the dorsal apodeme (*g*) of the volsellar plate (J, *lr*). The vol-
sellar musculature includes four distinct muscles (J, L), three of
which are extrinsic, and one intrinsic. Of the former, one is the usual
retractor of the volsella (*19*) inserted on the dorsal apodeme (*g*) of
the volsellar plate, another is the protractor (*18*) inserted on the
anterior apodeme (*apv*), the third (J, *20*) is a muscle observed by the
writer only in the vespids, which arises dorsolaterally on the parameral
plate and is inserted ventrally on the lower margin of the volsellar
plate. The single intrinsic muscle (J, *21*) extends from the anterior
apodeme (*apv*) to the dorsal apodeme (*g*) of the volsellar plate.

The volsellar structure described above in *Polistes* is the same in
Vespula and *Vespa.* There is no possible reason for doubting that the
free lobe identified as the digitus pertains to the volsella. It is difficult
to understand, therefore, why Boulangé (1924) terms this lobe the

"sagitta" in *Vespa,* and hesitates to identify it with the "pièce en trébuchet" (digitus) of Chalastogastra.

Vespula maculata (L.).—The phallus of *Vespula* (pl. 17 D, E) is deeply cleft between the large lateral basiparameral lobes and the broad, median aedeagus. Each basiparameral lobe ends in two small processes, of which the tapering dorsal one (*f*) corresponds with the parameral spine, and the shorter ventral one (*Pmr*) with the paramere of other species. The basiparameral lobes, the outer walls of which are continuous with the parameral plates (*lp*), cannot themselves be the parameres because their mesal walls are formed by the volsellar plates (F, *lv*). The aedeagus (D, E, *Aed,* H) terminates in a pair of falcate processes, proximal to which is the slitlike phallotreme on the ventral surface (H, *Phtr*) ; its lateral sclerites (*pv*) are prolonged into a pair of basal apodemes (*apa*), and the dorsal wall is produced into a tapering median arm (*c*) extended to the bases of the parameral plates (D, *c*). The volsellae have the same structure and musculature as in *Polistes* (F, G). The basal plate of each organ (*lv*) lies against the inner face of the corresponding basiparameral lobe, and has well-developed anterior and dorsal apodemes (G, *apv, g*). The digitus (F, G, *dig*) is of irregular shape, with relatively long basal rami (F, *mr, lr*) having the same relations to the volsellar plate (G) as in *Polistes.* The volsellar musculature is strongly developed (G).

Vespa crabro L.—The phallus of *Vespa* (pl. 18 A, B) resembles that of *Vespula,* but the parameres (*Pmr*) and the parameral spines (*f*) are relatively larger, and the aedeagus (*Aed*) is more nearly cylindrical. The elongate aedeagus (C, D) bears distally a pair of spatulate lobes, between the bases of which is the ventral phallotreme (D, *Phtr*) ; proximally the dorsal aedeagal wall is extended beyond the bases of the apodemes (*apa*) as a broad median plate (A, D, *c*), which abruptly tapers between the approximated basal ends of the parameral plates (A, *lp*) and gives off here two lateral processes (C, *k*) that articulate with the latter. The volsellae differ in no essential respect from those of *Vespula maculata.* The basal plate of each organ (pl. 17 M, O, Q, *lv*) lies against the mesal surface of the corresponding basiparameral lobe, and has the same musculature as in *Vespula* and *Polistes* (Q, muscle *20* shown in N). The free digital lobe is relatively small (O, *dig*), but it is attached to the volsellar plate by long basal rami (O, P, *lr, mr*) as in the other two species described.

The specialized structure and strong musculature of the vespid volsellae suggest that these organs play some particularly important part in the copulatory act. The volsellar mechanism, however, is not clear

from an anatomical study, since all the muscles of each organ are inserted on the volsellar plate, and the free digital lobe has no evident means of independent movement. Even the powerful muscles of the volsellar plate can give only slight movements to the volsella as a whole, considering the close membranous connections of the volsellar plate with the basiparameral lobe, but it is perhaps possible that the digitus has a rotary motion on the long hinge line of its mesal ramus (pl. 17 O, *mr*), produced by contraction of the muscles inserted on the dorsal apodeme (Q, *g*), with which the lateral ramus (O, *lr*) is closely associated.

XIII. SPHECOIDEA

Sphecius speciosus (Drury) (pl. 18 E-O), *Megastizus brevipennis* (Walsh) (pl. 19 A-G), *Microbembex monodonta* (Say) (pl. 19 H, Q, R; pl. 20 A, B), *Bicyrtes ventralis* (Say) (pl. 19 I-L), *Bembix spinolae* Lep. (pl. 19 M-P), *Philanthus gibbosus* (F.) (pl. 20 C-E), *Alysson oppositus* Say (pl. 20 F-H), *Zanysson texanus* (Cress.) (pl. 20 I-K), *Astata unicolor* Say (pl. 20 L, M), *Larra analis* F. (pl. 20 N, P, Q), *Crabro interruptus* (Lep.) (pl. 20 O, R), *Cerceris fumipennis* Say (pl. 21 A-E), *Dolichurus stantoni* (Ashm.) (pl. 21 F, G), *Gorytes phaleratus* Say (pl. 21 H-K), *Trypoxylon politum* Say (pl. 21 L, Q, R), *Trypoxylon frigidum* F. Sm. (pl. 21 M-P), *Rhinopsis canaliculata* (Say) (pl. 22 A-D), *Psen kohli* Fox (pl. 22 E-J), *Ammobia ichneumonea* (L.) (pl. 22 K-N, Q, R), *Podalonia luctuosa* (F. Sm.) (pl. 22 O, P, S, T), *Sceliphron caementarium* (Drury) (pl. 23 A-F), *Podium naematogastrum* Spin. (pl. 23 G, I), *Chalybion cyaneus* (F.) (pl. 23 H, J, L), *Sphex* sp. (pl. 23 K, M-R).

The abdomen of the Sphecoidea varies in shape and size largely in correlation with the length of the petiole (pl. 18 E; pl. 19 Q; pl. 21 A, F, H, L; pl. 22 A, E, K; pl. 23 A, H, M). The petiole, regardless of its length, is always the anterior part of segment *II* (first segment of the "postabdomen"), this segment being never given over entirely to the formation of the petiole. Posteriorly the exposed part of the abdomen ends with tergum *VIII* above, and sternum *VII, VIII,* or *IX* below according to the retraction of the terminal sternal plates, but sternum *VIII* is never reduced and united with sternum *IX* as in the Vespoidea, nor are sterna *VIII* and *IX* so curiously modified and closely associated with each other as in the Apoidea. Sternum *IX,* however, is sufficiently variable in shape to suggest that it should furnish characters of taxonomic value (pl. 18 I; pl. 19 C, G, H, J, M; pl. 20 D, G, I, M; pl. 21B, K, M, P; pl. 22 B, I, L, M, O; pl. 23

B, G). The ninth tergum of the Sphecoidea is in some cases a well-developed plate continuous across the dorsum above the base of the tenth segment (pl. 18 H; pl. 19 C; pl. 20 I; pl. 22 M); in others it is incomplete dorsally and divided into two lateral sclerites (pl. 23 C, G, N). The tenth segment is a small membranous lobe beyond the dorsum of segment *IX* (pl. 19 I, N; pl. 23 C, G, N, *X*). In some species it bears a pair of slender pygostyles (pl. 22 M; pl. 23 G, *Pgs*); in *Bembix spinolae* these appendages appear to be represented by a pair of thick hairy lobes (pl. 19 N, *Pgs?*). The functional anus (*An*) at the end of segment *X* is the aperture of a short invagination cavity into which opens the rectum (pl. 19 I).

The phallus of the Sphecoidea is so variable in shape and in the relative size of its parts that no characteristic of form can be ascribed to it (pl. 18 J, K, L; pl. 19 E, F, K, R; pl. 20 E, H, J, L, P, Q, R; pl. 21 C, G, J, N, O, Q, R; pl. 22 D, J, Q, R, T; pl. 23 D, L, O, P). The basal ring opens either anteroventrally, or so directly downward that its ventral margin underlaps the bases of the parameral and volsellar plates (pl. 21 J, R). The parameres (*Pmr*) are usually continuous with the parameral plates, but exceptionally (pl. 20 P, Q), they are partially separated from the latter. In *Trypoxylon politum* (pl. 21 N, O) each parameral plate (*lp*) bears two free parameral lobes (*Pmr*) of equal size. The aedeagus is generally long and cylindrical (pl. 18 O; pl. 19 E, K; pl. 20 E, H, K; pl. 21 D, Q, R; pl. 22 S; pl. 23 E, K), and has well-developed lateral plates, or penis valves (*pv*), which usually project distally as a pair of apical lobes, though they may be deeply separated by a median cleft (pl. 20 E; pl. 22 D, Q). In some species, however, the aedeagus is relatively short (pl. 20 R), and it may consist principally of the terminal lobes (pl. 18 J, K).

The volsellae present perhaps the most characteristic features of the sphecoid phallic complex. The volsellar plates are usually large sclerites entirely free from the parameral plates (pl. 19 F, O; pl. 21 G, J; pl. 22 D, T; pl. 23 P, *lv*), but they are commonly united with each other at their bases by a sclerotic bridge (pl. 18 M, N; pl. 19 L; pl. 23 I, J, Q, *j*), and sometimes there is present between them an intervening basal sclerite (pl. 22 N, P; pl. 23 J, *i*). Each volsellar plate generally bears a well-developed cuspis and digitus, the digitus particularly being variable in size and shape (pl. 18 M, N; pl. 19 L, P; pl. 20 B, C; pl. 22 C, H, N, P; pl. 23 F, I, J, Q). In *Bembix spinolae* (pl. 19 O, P) the cuspis (*cus*) is longer than the digitus (*dig*), but usually the cuspis is relatively small, and may be absent (pl. 20 R;

pl. 21 E). In *Trypoxylon* there is only one pair of volsellar lobes (pl. 21 O, Q, R, *vol*), and it is not clear what part of the volsellae they represent since there are no distinct volsellar plates.

XIV. APOIDEA

The pregenital part of the abdomen of male bees (except in Apidae) ends with the eighth tergum above and the seventh sternum below, and, with species in which the genito-anal chamber is ordinarily closed, it is always sternum *VII* that shuts against the lower margin of tergum *VIII*. Sterna *VIII* and *IX*, tergum *IX*, and the proctiger, or segment *X*, are then concealed within the genito-anal chamber. Tergum *VIII*, however, may be almost completely covered by tergum *VII*, and sternum *VII* may be underlapped by sternum *VI*, or sometimes sternum *V* conceals all the succeeding sternal plates. On the other hand, the genito-anal chamber is not always a closed cavity; when it is open the phallus may be either visible within it, or partly protruding, and the margin of the seventh sternum does not correspond in shape with the lower edge of the eighth tergum. The ninth tergum is represented only by a pair of lateral sclerites in the dorsal wall of the genito-anal chamber. These marginal remnants of tergum *IX* usually extend posteriorly to the sides of the anus, but they have no dorsal connection with each other. The proctiger, or segment *X*, forms the posterior part of the roof of the genito-anal chamber in which usually there is a subanal plate, but only the anal lips of the tenth segment project as a free lobe. Pygostyles are absent. The functional anal opening leads into a secondary invagination cavity having the true rectal opening in its anterior wall. The sternal plates of the genital region are highly variable in form and relative size, but the eighth and the ninth particularly have a tendency to assume unusual and often fantastic shapes. Sternum *IX* is generally retracted above sternum *VIII*, and is closely associated with the ventral side of the phallus, which it supports. Only in Apidae are these two sterna consecutive and united with each other.

The phallus of the Apoidea has the usual hymenopterous structure except in the Apidae, in which family the ectophallus is more or less reduced and the endophallus highly developed. The parameres are either continuous from the parameral plates or articulated on them. The volsellae are always small or vestigial when present, and may be entirely absent. The principal distinctive feature of the apoid phallus pertains to the aedeagus, in which the usual lateral plates, or penis valves, are generally more or less separated from a median penial

lobe to form a pair of free lateral arms commonly known as the *sagittae*. Because of the reduction or absence of the true volsellae, the sagittae have sometimes been supposed to be the volsellar lobes, but their aedeagal origin is clearly shown by the fact that they are continuous basally with the aedegeal apodemes on which the usual aedeagal muscles are attached. Moreover, the degree of separation of the sagittae from the penis is variable, and the sagittae are always attached at least to the base of the latter. It is shown by Zander (1900) in *Bombus* that the sagittae are the penis lobes of the phallic rudiments, but that, instead of uniting in the usual way to form an aedeagus, they grow out as two independent processes, which finally unite only at their bases, forming here a median structure around the aperture of the ductus ejaculatorius, which later grows out as the penis. Among the Apoidea all gradations may be found from a condition in which the aedeagus has the usual single structure, to others in which the penis valves project as free processes at the end of the organ, and finally become independent lateral arms, or sagittae, but the last condition is that most prevalent in the group.

The order in which the families are given in the following descriptions is approximately that usually followed by taxonomists, but, in the structure of the phallus, the Andrenidae, the Megachilidae, and the Apidae stand apart from the others, because in these three families the penis valves are not separated from the membranous middle part of the aedeagus. It is not here claimed that this feature relates these families to one another, or gives them a generalized status among the Apoidea; the fact mentioned, however, is worthy of attention, since it is not clear how these three groups could separately revert to a generalized condition.

ANDRENIDAE.—*Andrena crataegi* Robt. (pl. 24 A-C, L-P), *Andrena fragilis* F. Sm. (pl. 24 D-K).

The sternal plates of segments *VIII* and *IX* are retracted in the usual manner and are covered by sternum *VII* (pl. 24 A). Sterna *VII, VIII,* and *IX* of *Andrena crataegi* and of *A. fragilis* are shown at A-C and D-F, respectively. The phallus is of simple form (G, H, L, M) ; in *A. fragilis* (G) the parameral plates (*lp*) bear dorsally a pair of long parapenial lobes (*pa*) projecting above the aedeagus (*Aed*). Volsellae are present, but much reduced (H, *Vol*) ; each consists of a small, strongly musculated basal plate (I, J, P, *lv*) and of two free lobes that are evidently the cuspis and the digitus (*cus, dig*). The aedeagus is a short, thick structure (K, N, O) with strong basal apodemes (*apa*) and a pair of tapering distal processes, but otherwise the lateral plates, or penis valves, are incorporated in the

body of the organ, so that there are no free sagittal arms of the aedeagus.

PANURGIDAE.—*Perdita octomaculata* (Say) (pl. 24 Q-U), *Halictoides calochorti* Ckll. (pl. 24 V-Y).

The forms of the retracted eighth and ninth sterna of *Perdita octomaculata* are shown at R and S of plate 24, those of *Halictoides calochorti* at V and W. The phallus of these species (Q, Y) is typically apoid in that the aedeagus consists of a median penis and lateral sagittal arms. In *P. octomaculata* the aedeagus (T) has a long undivided basal part, from which the apodemes (*apa*) arise proximally and the sagittae (*sag*) distally, and the bilobed membranous penis (*pen*) projects from beneath the bases of the sagittae; in *H. calochorti* (Y) the penis (*pen*) is short and lies between the bases of the sagittae (*sag*). The small volsellae arise ventrally at the sides of the aedeagus (Q, *Vol*) ; each organ is two-lobed in *P. octomaculata* (U), but consists of a single lobe in *H. calochorti* (X, *Vol*).

HYLAEIDAE.—*Hylaeus basalis* (F. Sm.) (pl. 25 A-C, G-K), *Hylaeus cressoni* (Ckll.) (pl. 25 D-F, L, M), *Colletes inaequalis* Say (pl. 25 N, O, T-V), *Colletes armatus* Patt. (pl. 25 P-S).

The sternal plates of segments *VIII* and *IX* attain highly diversified forms in this family. Those of *Hylaeus basalis* are illustrated at B and C of plate 25, those of *H. cressoni* at D and E, the latter being shown also in their natural superposed position as seen from below at F. The corresponding plates of *Colletes inaequalis* and *C. armatus* are given at N and O, and at P and Q, respectively. The ninth tergum is represented by a pair of lateral sclerites (G, *IXT*) in the membranous dorsal wall of the genito-anal chamber beneath tergum *VIII*, and between their posterior ends is a median subanal plate (*l*) of the proctiger. The phallus is variable in the size and shape of the parameres and in the form of the sagittae. The parameres are broad, spatulate extensions of the parameral plates in *Hylaeus basalis* (H, I, *Pmr*), tapering lobes in *H. cressoni* (L, M), elongate in *Colletes armatus* (R), oval with apical points in *C. inaequalis* (T). The sagittae are large, free, distal prolongations of the penis valves, generally undivided (L, M, R, T, U, *sag*), but in *Hylaeus basalis* each sagitta is itself bifurcate (I, K, *sag*). The penis is a short median menbranous lobe between the bases of the sagittae (U, *pen*). The volsellae are small ; in *Hylaeus basalis* each volsella consists of a single lobe resting against the ventral margin of the parameral plate (I, M, *Vol*), but in the two species of *Colletes* there is a distinct basal volsellar plate (S, *lv*) ending with a cuspis (S, V, *cus*) and bearing an articulated digitus (*dig*).

CTENOPLECTRIDAE.—*Macropis ciliata* Patt. (pl. 26 A-G).

Figures A, B, and C of plate 26 give the shapes and relative sizes of the sternal plates of segments *VII, VIII,* and *IX* in the single representative studied in this family. The phallus (D) is characterized by the small size of the basal ring (*BR*), the three-branched form of the parameres (D, E, *Pmr*), the strong development of the sagittae (D, G, *sag*), and the great reduction of the penis (G, *pen*). The inconspicuous volsellae are borne on the ventral margins of the parameral plates beneath the base of the aedeagus (E, *Vol*). Each organ consists of a small basal plate (F, *lv*) set into an emargination of the corresponding parameral plate (*lp*) and invaginated above the latter. The plate is produced into a thick cuspis (*cus*), and bears mesally opposed to the cuspis a short, toothed digitus (*dig*).

ANTHOPHORIDAE.—*Anthophora abrupta* Say (pl. 26 H-N), *Anthophora pallipes, Diadasia australis* (Cress.) (pl. 26 O-R), *Tetralonia atriventris* (F. Sm.) (pl. 26 S-V), *Melissodes* sp. (pl. 27 A-E).

The sternal plates of the genital region are variable in the degree of their modifications from relatively simple to complex forms, as seen in *Anthophora abrupta* (pl. 26 H, I, J), *Diadasia australis* (O, P), *Tetralonia atriventris* (U, V), and *Melissodes* sp. (pl. 27 A, B). The phallus (pl. 26 K, L, Q, S; pl. 27 C, D) is characterized by the articulation of the parameres on the parameral plates. In the two species of *Anthophora* (pl. 26 K, L) and in *Melissodes* sp. (pl. 27 C, D) the parameral plates (*lp*) are produced into large basiparameral lobes at the sides of the aedeagus, and the parameres (*Pmr*) are relatively small; in *Anthophora* they appear as mere appendicular processes of the basiparameral lobes (pl. 26 K). The basiparameral lobes themselves, as in *Anthophora pallipes* (not illustrated), may be irregular and branched. A more usual structure is seen in *Diadasia australis* (pl. 26 Q) and in *Tetralonia atriventris* (S). The aedeagus has strongly developed, often irregular sagittae (pl. 26 M, N, R, T; pl. 27 E, *sag*) continuous proximally with the aedeagal apodemes (*apa*). The median penis (*pen*) is a short membranous tube, but at its base is a strong dorsal plate (pl. 26 M, Q, R, S; pl. 27 C, *m*), which supports the bases of the sagittae, and may articulate by lateral extensions with the parameral plates (pl. 26 S; pl. 27 C). Volsellae were not observed in the anthophorid species studied.

NOMADIDAE.—*Nomada bella* Cress. (pl. 27 F-J).

The sternal plates of the genital region in *Nomada bella* are relatively simple (pl. 27 F, G), though sternum *IX* bears a long, median, distal arm. The phallus, shown in dorsal view at H, presents the usual parts. The parameres (*Pmr*), which are divided each into a larger

dorsal lobe and a smaller ventral lobe (J, *Pmr*), are flexibly articulated on the parameral plates but appear to have no muscles to move them. The volsellae are reduced to a pair of small, simple plates (J, *Vol*) visible from below as two small lobes between the approximated lower edges of the parameral plates. The aedeagus (I) consists of lateral sagittae (*sag*) and a median, tubular, membranous penis (*pen*). The sagittae articulate on the parameral plates by their widely divergent bases (H), which are narrowly bridged through the base of the penis.

MELECTIDAE.—*Melecta armata* (Panz.) (pl. 27 K-Q), *Crocisa crucifera* Ckll. (pl. 27 R-V; pl. 28 A, B), *Triepeolus concavus* (Cress.) (pl. 28 C-N).

Examples of the forms assumed by the genital sterna in this family are shown at K, L, R, and S on plate 27, and at D, F, and G on plate 28. A progressive dissection of the parts of the genital segments is illustrated at C-I on plate 28. In the usual condition (C) the genito-anal chamber at the end of the abdomen is closed by the approximation of sternum *VII* against tergum *VIII*. The seventh sternum itself (D) is largely concealed, but when removed there is exposed above it (E) the entire ventral margin of tergum *VIII,* together with sterna *VIII* and *IX* superposed on each other. Above the sternal plates is the cavity containing the phallus and the proctiger, which cavity is more fully exposed on removal of sternum *VIII* (H), leaving sternum *IX* in its natural position. The phallus being omitted in these figures, there are seen on the roof of the genito-anal chamber two lateral sclerites (H, *IXT*), which are the remnants of tergum *IX.* Finally, on taking away the enclosing eighth tergum (I) it is seen that the dorsal wall of the chamber is prolonged distally beyond the ninth tergal plates (*IXT*) as the ventral wall of a short flattened median tube (*X*), which is the tenth abdominal segment, or proctiger, having the anus at its extremity.

The phallus of the Melectidae resembles that of Anthophoridae and Nomadidae in that the parameres are flexible on the parameral plates, and the sagittae are strongly developed lateral lobes of the aedeagus (pl. 27 M, T; pl. 28 J). In *Crocisa crucifera,* at least, each paramere is provided with a muscle (pl. 28 B) arising on the parameral plate. Volsellae are present but are inconspicuous. In *Melecta armata* and *Crocisa crucifera* each volsella consists of a small basal plate and of two free lobes turned upward (pl. 27 O; pl. 28 A, *Vol*), but the identity of the lobes is not clear. In a ventral view (pl. 27 N, U) the volsellae are seen lying mesad of the bases of the parameres. The sagittae of the aedeagus are variable in form and size (pl. 27

M, Q, T, V; pl. 28 J, M, N, *sag*), as is also the penis (*pen*), which
lies between them. In *Triepeolus concavus* the entire aedeagus is
particularly large and strongly developed (pl. 28 J, M, N), and is
supported from below on a pair of large ventral lobes projecting
mesally from the parameral plates (K, L, *o*). The sagittae exceed
the parameres in size (J) and the penis (*pen*) extends beyond the
sagittae. The lateral walls of the penis are strengthened by a pair
of elongate sclerites (J, M, *x*), and the base of the organ contains
a transverse dorsal sclerite (*m*) supporting the sagittae laterally. That
the lateral sclerites of the penis are not the primary penis valves is
evident from the fact that they are not produced into the aedeagal
apodemes, which are basal arms of the sagittae (N, *apa*). The phal-
lotreme is a large subterminal opening on the ventral side of the
penis (N, *Phtr*).

MEGACHILIDAE.—*Megachile* sp. (pl. 28 O-T), *Ashmeadiella
bucconis* (Say), *Hoplites albifrons* (Kirby), *Heriades variolosa*
(Cress.), *Osmia lignaria* Say, *Prochelostoma philadelphi* (Robts.),
Coelioxys sp. (pl. 29 A-F), *Coelioxys texana* Cress., *Anthidium
porterae* Ckll.

The abdomen ends with tergum *VII*, which is strongly deflexed
or produced posteriorly, and generally armed with several spinous
processes (pl. 28 O, P; pl. 29 A); but the apex of tergum *VIII* is
usually exposed beneath the seventh tergum (pl. 28 O, P) and its
lateral parts extend forward to the sides of sternum *VIII* (P, Q).
The exposed part of the abdominal venter may end with sternum *V*,
but generally sternum *VI* is the last visible sternal plate (pl. 28 O;
pl. 29 A). Sternum *VII* may be entirely hidden above *VI*, but it
always fits into the concave lower margin of tergum *VIII* and thus
closes the genito-anal cavity when the phallus is fully retracted.
Sterna *VIII* and *IX* are relatively small and always mostly concealed;
sternum *VIII* may be reduced to a narrow plate or transverse bar
(pl. 28 Q; pl. 29 C), but sternum *IX* is a triangular or elongate
plate (pl. 28 R; pl. 29 C) closely associated with the ventral side of
the phallus.

The phallus is usually of simple form with slender parameres and
a relatively large aedeagus (pl. 28 S, T; pl. 29 E, F). The ventral
surfaces of the parameral plates are characteristically produced into
a pair of oval lobes (*o*). These lobes have been regarded as the
volsella (see Sandhouse, 1939), but they have none of the features
of a volsella, being entirely continuous with the parameral plates and
not provided with muscles. They are analogous to the similar ventral
lobes of the parameral plates that recur in various hymenopterous

groups, already noted among the bees in the melectid *Triepeolus concavus* (pl. 28 K, L, *o*), and which in the megachilid *Anthidium porterae* (not illustrated) attain a length almost equal to that of the parameres themselves. True volsellae are absent in Megachilidae.

The aedeagus of the Megachilidae, as in Andrenidae and Apidae, retains the generalized hymenopterous structure in that its lateral sclerites, or penis valves, are not sufficiently separated from the median part of the organ to form a pair of "sagittae," though their terminal parts may project as free apical processes of the aedeagus (pl. 28 S, T; pl. 29 D). The middle membranous part of the aedeagus is sometimes omitted in taxonomic illustrations (as by Sandhouse, 1939, in *Osmia*) in order to show more clearly the outlines of the lateral sclerites, but this practice is misleading anatomically, and fails to record a characteristic feature of the Megachilidae. Within the aedeagus is an ample endophallic sac opening at the distal end of the median membranous part of the organ.

XYLOCOPIDAE.—*Xylocopa virginica* (L.) (pl. 29 G-M).

The abdomen of the male in *Xylocopa,* as in the other bees, terminates with tergum *VIII* above and sternum *VII* below. When the seventh sternum is removed, therefore, the genito-anal chamber containing the phallus and the proctiger is exposed beneath the eighth tergum (pl. 29 G), and lying anterior to it are seen the eighth and ninth sterna (*VIIIS, IXS*). These sternal plates, however, instead of having the curious shapes characteristic of most other apoid families, are simple transverse arcs (G, H, I, *VIIIS, IXS*) except that sternum *IX* has a strong median apodeme (*aps*). Sternum *VIII* lies transversely between the anterior ventral angles of tergum *VIII* (G), but the ends of sternum *IX* curve upward into the dorsal wall of the genito-anal chamber where they meet the anterior ends of a pair of sclerotic bars lying laterally in the dorsal wall of the chamber. These bars (G, *IXT*) are remnants of the ninth abdominal tergum. Each bar (I, *IXT*) is enlarged anteriorly as a small plate (*t*) and is produced posteriorly in a slender arm reaching the side of the anus, but has no dorsal connection with the bar of the opposite side. The region of the tenth segment (G, *X*), or proctiger, is a broad membranous area between the posterior arms of the ninth tergal sclerites, bearing the functional anus (*An*), but only the anal lips project as free lobes. The wide functional anal opening (*An*) leads into an invaginated pocket having the true anus in its anterior wall.

The phallus of *Xylocopa virginica* is short, broad, and strongly sclerotized (pl. 29 J, K). The basal ring (*BR*) is narrow above and below, and is widely open anteroventrally (K); the wide parameral

plates (*lp*) are produced into thick basiparameral lobes, of which the
terminal parts may be regarded as the parameres (*Pmr*), though it is
questionable if they are properly so designated. Volsellae are absent.
The aedeagus (J, *Acd*) is broad and almost rectangular in shape.
The strong lateral sagittae (J, K, L, *sag*) are sharply decurved dis-
tally (M), produced proximally into the aedeagal apodemes (L, M,
apa), and bear laterally a pair of basal articular knobs (*e*). The
median penis (L, *pen*) is a wide membranous tube, supported basally
on a transverse dorsal plate of the aedeagus (*m*), which is united
laterally with the bases of the sagittae.

BOMBIDAE.—*Bombus americanorum* (F.) (pl. 29 N, O; pl. 30
A-G), *Bombus lapidarius* (L.) (pl. 29 P).

The rounded end of the male abdomen in *Bombus* is formed by the
eighth tergum, against which the seventh sternum closes from below
and shuts in the genito-anal chamber, concealing thus within the latter
not only the phallus and the proctiger, but also the eighth and the
ninth sternal plates. In *Bombus americanorum* sternum *VIII* is a
thin, crescent-shaped plate (pl. 29 N) having its lateral angles pro-
longed to meet the basal angles of tergum *VIII*. Sternum *IX*, which
is retracted above sternum *VIII*, is a relatively small, median plate
(O, *IXS*) with long basal arms extending laterally and dorsally into
the roof of the genital chamber, where they meet the outer branches
of the Y-shaped tergal sclerites of the ninth segment (*IXT*). The
latter, as in *Xylocopa* (G), have posterior arms extending to the sides
of the anus, but are not connected dorsad of the latter.

The phallus of *Bombus* is large and strongly constructed (pl. 29 P;
pl. 30 A, B). It consists of a basal ring (*BR*) with a wide ventral
foramen, a pair of elongate parameral plates (*lp*) bearing each two
small apical parameral lobes (*Pmr*), and an aedeagus with well-
developed sagittae (*sag*) flanking the median penis (*pen*). The
parameral plates are firmly united dorsally by a strong basal bridge
(pl. 30 C).

The two pairs of terminal lobes borne by the parameral plates in
the Bombidae have often been regarded as the parameres ("squamae")
and the volsellae. A close examination, however, shows that the two
lobes of each pair are connected both laterally (pl. 30 F) and mesally
(G) by membranes, which leave only the distal parts of the lobes
free from each other. This connection suggests that the two lobes
are merely subdivisions of the paramere (*Pmr*). The relatively short
dorsal lobe (*q*) is articulated to the distal end of the parameral plate
(*lp*); the outer wall of the ventral lobe (*r*) is extended proximally
as a long sclerite articulated basally on the ventral margin of the

parameral plate (B, G), and is thus comparable in position with a volsellar plate. The fact, however, that the sclerite in question (*r*) is partially united by membrane with the dorsal parameral lobe (*q*), and has no muscles, while the volsellae are always strongly musculated, would contradict the more superficial evidence of its volsellar nature. Finally, it has been shown by Zander (1900, fig. 5) that the two lobes on each side (*q, r*) are formed ontogenetically as secondary subdivisions of the primary "valva externa" (paramere), and that the volsella of *Bombus* is developed at the median ventral angle of the parameral plate, and never becomes more than a minute scale. The true volsellae of *Bombus americanorum*, therefore, are probably the small lobes borne directly on the lower angles of the parameral plates (G, *Vol*). It is scarcely to be supposed that volsellae would be well developed in Bombidae, while in other higher families of Apoidea they are vestigial or absent.

The aedeagus of *Bombus americanorum* has the typical apoid structure (pl. 30 D, E). The penis valves are strong sagittal processes (*sag*) arising laterally at the base of the median penis (*pen*) and continuous proximally with the aedeagal apodemes (*apa*). The thick membranous penis has a dorsal plate (D, *m*) in its base, prolonged distally as a median sclerite (*n*) known as the "spatha" (the "uncus" of Franklin, 1912, 1913), the tip of which projects as a free point over the end of the penis. The phallotreme is a large subterminal aperture on the ventral side of the penis (E, *Phtr*) and leads into a spacious endophallic sac (Enph). In *B. lapidarius* (pl. 29 P) the aedeagus is of similar structure, though the penis is more slender and the sagittae are longer.

MELIPONIDAE.—*Trigona testacea cupira* (F. Sm.) (pl. 30 H-M), *Trigona compressa* (Latr.) (pl. 30 N, O), *Melipona favosa* (F.) (pl. 31 A-F).

The last exposed segmental plates of the abdomen are tergum *VIII* above and sternum *VII* below (pl. 30 H), but the two plates are not applied to each other, and the terminal parts of the phallus freely protrude from the open genito-anal chamber. Tergum *VIII*, moreover, is small and mostly covered by tergum *VII;* its lateral parts are extended forward as tapering arms in the dorsal wall of the genito-anal chamber (pl. 30 J; pl. 31 D, *VIIIT*). The concealed eighth and ninth sterna (pl. 30 I; pl. 31 A, *VIIIS, IXS*) are closely associated with each other in the ventral part of the genital chamber; the elongate ninth sternum is retracted above the eighth and supports the base of the phallus. The tergum of segment *IX*, as in *Xylocopa* and *Bombus*, is represented by a pair of slender lateral sclerites in

the dorsal wall of the genital chamber (pl. 30 J ; pl. 31 D, *IXT*) extending posteriorly to the sides of the proctiger (*X*).

The phallus of *Trigona testacea cupira* (pl. 30 K, L), of *Trigona compressa* (pl. 30 N, O), and of *Melipona favosa* (pl. 31 E, F) is simple in form, but the long slender parameres (*Pmr*) arise laterally from the parameral plates (*lp*) and at points near the bases of the latter. Volsellae are absent. The aedeagus consists of a pair of tapering sagittal arms (*sag*) arising from thick bases, and of a median membranous penis (*pen*), the variable size of which suggests that it is partly the everted endophallus. The base of the penis contains a large dorsal plate (pl. 30 K, N ; pl. 31 E, *m*) supporting laterally the bases of the sagittae. From the enlarged basal part of each sagitta there extends anteriorly a flat, free dorsal lobe (*s*), either membranous or sclerotic, that partially overlaps the parameral plate (*lp*) of the same side. The opening into the sagitta from the interior of the aedeagus is reduced to a small foramen (pl. 30 M) just behind the basal lobe (*s*), mesad of which arises the short aedeagal apodeme (*apa*). The proximal origin of the parameres on the parameral plates and the presence of the basal lobes of the sagittae constitute two unusual features of the phallus that would appear to be distinctive of the Meliponidae.

APIDAE.—*Apis florea* F. (pl. 31 I, J, L), *Apis indica* F. (pl. 31 H, M, N), *Apis mellifera* L. (pl. 31, G, K, O ; pl. 32 A-O ; pl. 33 A-D).

The male abdomen of the Apidae ends with the deflected eighth tergum above (pl. 31 G, H, O, *VIIIT*) as in other bees, but the ninth sternum (*IXS*) may be well exposed, though the eighth is always concealed above the seventh. The ninth tergum is reduced to a pair of small sclerites lying laterally in the dorsal wall of the genital chamber (pl. 31 O, *IXT*) anterior to the base of the proctiger (*X*), and each tergite bears internally an apodemal process (K, *apt*) on which muscles are attached. The ninth sternum is well developed in *Apis mellifera* (G, O, *IXS*) and *A. indica* (H, N), though its lateral extremities in these two species are widely separated from the ninth tergal sclerites in the dorsal wall of the genital chamber (N, O, *IXT*). In *A. florea,* on the other hand, the ninth sternum is reduced to a narrow transverse bar (L, *IXS*), but it connects laterally with the ninth tergal sclerites (*IXT*). The concealed eighth sternum is a narrow transverse plate in *A. florea* (*VIIIS*) with tapering lateral apodemes (*ap*) ; in *indica* and *mellifera* (O) it is attenuated medially and expanded laterally, where it meets the eighth tergum (*VIIIT*), and gives off anteriorly a pair of slender apodemal arms (*ap*).

The male genital organ of the Apidae is characterized by a reduction of the ectophallus and a great elaboration of the endophallus to form a large eversible structure, which becomes the functional intromittent organ usually termed the penis. The ectophallus is so greatly reduced in *Apis indica* and *A. mellifera* that it is difficult to identify its remnants. In *A. florea,* however, the ectophallic parts are retained in almost typical hymenopterous form (pl. 31 I, J), except for the reduction of the parameres and the absence of a differentiated basal ring. The large base of the phallus contains dorsally (I) a pair of parameral plates (*lp*), each of which ends distally in a small lobe (*Pmr*), evidently the reduced paramere, bearing a brush of long setae. The aedeagus is a thick, obtuse median lobe of the phallus with large lateral sclerites, or penis valves (*pv*), provided with the usual basal apodemes (J, *apa*), and embracing distally a wide aperture, the phallotreme (I, *Phtr*), leading into an extensive endophallic sac. Ventrally (J) the base of the phallus is almost entirely occupied by the basal foramen.

Closely associated ventrally with the base of the phallus in *Apis florea* is the narrow, transverse sternal bar of the ninth segment (pl. 31 J, *IXS*). The somewhat expanded lateral parts of the bar present three short branches, one of which on each side adjoins the corresponding lateral sclerite of the ninth tergum (L, *IXT*), while another (*u*), it should be noted particularly (J), abuts against the anterior margin of the ventral part of the parameral plate (*lp*) close to the parameral lobe (*Pmr*). The primitive relations of the ninth sternum to the ninth tergal sclerites and to the base of the phallus that are preserved in *Apis florea* will help to explain certain modifications that have taken place in the other species of *Apis.*

The phallus of *Apis indica* (pl. 31 M) and of *A. mellifera* (pl. 32 A, B) differs from that of *A. florea* principally in the reduction of the parameral plates to small lateral sclerites (*lp*) overlapping the basal angles of the penis valves (*pv*), and the separation of the penis valves by a broad, soft, median dorsal lobe of the phallic integument (*w*) overhanging the phallotreme (*Phtr*), which last is fully exposed when the penis valves are pressed apart (pl. 32 B). Each parameral plate bears a small setigerous parameral lobe (*Pmr*) as in *florea.* Basally each penis valve is produced into a small apodemal arm (pl. 32 N; pl. 33 C, *apa*) on which are inserted a pair of muscles (pl. 33 D, *12, 13*) arising on the corresponding parameral plate (*lp*). There can thus be little question as to the identity of the genital lobes in these species of *Apis,* which sometimes have been termed "claspers" (Snodgrass, 1925).

The ninth sternal plate of *Apis indica* and *A. mellifera,* though well developed ventrally (pl. 31 G, H, O, *IXS*), does not, as in *florea* (L), extend laterally to the tergal sclerites of its segment, because the parameral plates of the phallus intervene laterally between the sternum and the tergites (N, O, *lp*). It was observed in *florea,* however, that an arm of the sternum on each side (L, *u*) abuts against the base of the parameral plate. In *mellifera* and *indica* a marginal ridge of the parameral plate (M, N, *u*) has the relation of a link between the sternum (N, *IXS*) and the tergite (*IXT*). It would appear, therefore, that the parameral plates of *mellifera* and *indica* have incorporated into their basal parts the primitive lateral arms of the ninth sternum, and this inference is substantiated by the fact that there is attached on the upper end of the basal ridge of each parameral plate a muscle from the eighth sternum (pl. 33 D,*11*), which corresponds with the lateral intersternal muscles (*11*) of the preceding segments (pl. 33 B).

The endophallus is a large and complex organ in each of the three species of *Apis* here studied. Its form in *A. mellifera* and its size relative to that of the ectophallus are shown at D of plate 32. The phallic structure of the Apidae gives no suggestion of derivation from that of any other family of the Apoidea. The apid phallus, as developed in *Apis florea,* would appear to be of a generalized type of structure, since the penis valves are integral parts of the aedeagus. The disparity between the apid phallus and the phallic structure of other bees is nowhere more evident than between the Apidae and the Meliponidae.

The development of the ectophallus of *Apis mellifera* has been followed in detail by Michaëlis (1900) and by Zander (1900). The principal stages in the growth of the organ are readily seen in whole specimens. A late larval instar shows on the ventral side of the ninth abdominal segment a small oval genital disk with two slight thickenings (pl. 32 F, G, *gd*). Beneath the disk, however, in the integument of the succeeding instar developing within the external skin, there is a small oval pit (H) containing a pair of rounded lobes, which are the phallic rudiments. With later development these primary phallic lobes unite basally, and divide distally into four secondary lobes. At the transformation to the pupa the immature phallus is exserted and appears now as a thick body with a broad base and four terminal lobes projecting from the end of the pupal abdomen between the proctiger and the ninth sternum (M). Viewed from above (I) or below (J) the pupal phallus is seen to be roughly triangular. The thick median terminal lobes are the penis valves (*pv*) with the slitlike

5

phallotreme between them; the smaller lateral lobes are evidently the parameres (*Pmr*), while the lateral parts of the broad base of the organ represent the areas of the parameral plates (*lp*). The latter are surrounded at this stage by lateral extensions of the ninth sternum (J, M, *IXS*). In a horizontal section of the pupal phallus (K), Zander shows the rudiments of a pair of aedeagal apodemes (*apa*) arising from the bases of the penis lobes and projecting proximally within the parameral plates ("valvae externae"). The large internal tube of the phallus, termed by Zander the "ductus ejaculatorius," is clearly the endophallus. The pupal organ shows no change externally during the pupal period, but within the pupal cuticula the imaginal organ completes its development and attains the final structure before the pupal skin is shed (L, O). In the mature stage the endophallus has acquired the highly complex form and structure of the eversible "penis" of the drone bee (D, *Enph*).

The general abdominal musculature of *Apis mellifera* is much more strongly developed in the drone than in either the queen or the worker, but in segments *I* to *VI*, inclusive, the same muscles are present in each sex. The entire musculature of the "postabdomen" of the drone, which has been described by Morison (1927), is shown at B of plate 33. In segments *IV, V,* and *VI* there are present in each segment 11 muscles, including a pair of spiracular muscles (not shown), but not the fibers of the dorsal and ventral diaphragms. The somatic muscles in any one of these segments comprise three intertergal dorsal muscles (*1, 2, 3*), three tergosternal lateral muscles (*6, 7, 8*), and three intersternal ventral muscles (*9, 10, 11*). In segment *VII* there is only one lateral muscle (*7*), and only one ventral muscle, which is the lateral internal ventral (*11*) attached posteriorly on a long apodemal arm (C, D) of sternum *VIII*. Segment *VIII* has but one dorsal muscle (B, *2*), one lateral muscle (*7*), and one ventral muscle (*11*). The last arises laterally on the eighth sternum (B, D) but is inserted posteriorly on the dorsal apodeme of the small parameral plate of the phallus (D, *lp*). This muscle, however, so clearly falls in line with the lateral internal ventral muscles (*11*) of the preceding segments that its identity as one of this series can scarcely be questioned. The muscle relations, therefore, conform with the evidence already given which suggests that the anterior marginal ridge of the parameral plate in *Apis indica* and *A. mellifera* (C, *u*) is derived from the lateral part of the ninth sternum.

The intraphallic musculature of *Apis mellifera* includes on each side only the two small muscles (pl. 33 D, *12, 13*) converging from the parameral plate (*lp*) to their insertions on the apex of the basal

apodeme of the penis valve (pv). Their size and position might suggest, as observed by Morison (1927, p. 456), that these muscles represent the external intersternal protractors (B, 9) of the pregenital segments; there can be little doubt, however, that they are remnants of the usual aedeagal musculature of other species. The only other phallic muscle of the honey bee is a slender muscle (D, 14) extending from the apex of the aedeagal apodeme to the mucous gland of the same side, on which it is attached just laterad of the end of the vas deferens.

XV. REFERENCES

AUDOUIN, V.
    1821. (See Latreille, 1821.)
BECK, D. E.
    1933. A morphological study of the male genitalia of various genera of bees. Proc. Utah Acad. Sci., vol. 10, pp. 89-137, pls. 1-8.
BOULANGÉ, H.
    1924. Recherches sur l'appereil copulateur des Hyménoptères et spéciale- ment des Chalastogastres. Mém. et Trav. Fac. Cathol. Lille, fasc. 28, 444 pp., 141 text figs., 3 pls.
CHRISTOPHERS, S. R., and CRAGG, F. W.
    1922. On the so-called "penis" of the bedbug (Cimex lectularius) and on the homologies generally of the male and female genitalia of this insect. Indian Journ. Med. Res., vol. 9, pp. 445-463, pls. 19-21.
CRAMPTON, G. C.
    1919. The genitalia and terminal abdominal structures of males, and the terminal structures of the larvae of "chalastogastrous" Hymenop- tera. Proc. Ent. Soc. Washington, vol. 21, pp. 129-151, pls. 9-12.
DUFOUR, L.
    1841. Recherches anatomiques et physiologiques sur les Orthoptères, les Hyménoptères et les Névroptères. Mém. Acad. R. Sci. Inst. France, Sav. Etrang, vol. 7, pp. 265-647, 13 pls.
ELSE, F. L.
    1934. The developmental anatomy of male genitalia in Melanoplus differen- tialis (Locustidae, Acrididae, Orthoptera). Journ. Morph., vol. 55, pp. 577-609, 4 pls.
FRANKLIN, H. J.
    1912, 1913. The Bombidae of the New World. Trans. Amer. Ent. Soc., vol. 38, pp. 177-486; vol. 39, pp. 73-200, 22 pls.
GEORGE, C. J.
    1928. The morphology and development of the genitalia and genital ducts of Homoptera and Zygoptera as shown in the life histories of Philaenus and Agrion. Quart. Journ. Micr. Sci., vol. 72, pp. 447- 485, pls. 27-29.
HARTIG, T.
    1837. Die Familien der Blattwespen und Holzwespen, nebst einer allge- meinen Einleitung zur Naturgeschichte der Hymenoptera. Berlin.

KLUGE, H. E .

    1895. Das männliche Geschlechtsorgan von Vespa germanica. Archiv Naturg., vol. 61, Bd. 1, pp. 159-198, pl. 10.

LATREILLE, P. A.

    1821. Report on mémoire by Audouin, "observations sur les appendices copulateurs mâles des insectes, et particulièrement des bourdons. Ann. Gen. Sci. Phys., vol. 8, pp. 285-289.

LINDSAY, EDER

    1940. The biology of the silverfish Ctenolepisma longicauda Esch., with particular reference to its feeding habits. Proc. Roy. Soc. Victoria, vol. 52, pp. 35-83, 12 text figs., 2 pls.

MEHTA, D. R.

    1933. On the development of the male genitalia and the efferent genital ducts in Lepidoptera. Quart. Journ. Micr. Sci., vol. 76, pp. 35-61, 18 figs.

METCALFE, MARGOT E.

    1932. The structure and development of the reproductive system in the Coleoptera with notes on its homologies. Quart. Journ. Micr. Sci., vol. 75, pp. 49-129, pls. 7-10.

    1932a. Notes on the structure and development of the reproductive organs in Philaenus spumarius L. Quart. Journ. Micr. Sci., vol. 75, pp. 467-481, pls. 27, 28.

MICHAËLIS, G.

    1900. Bau und Entwicklung des männlichen Begattungsapparates der Honigbiene. Zeit. wiss. Zool., vol. 67, pp. 439-460, pl. 26.

MORISON, G. D.

    1927. The muscles of the adult honey-bee. (Apis mellifera L.). Quart. Journ. Micr. Sci., vol. 71, pp. 395-463, 12 figs.

NIXON, G. E. J.

    1936. New parasitic Hymenoptera from Africa (Proctotrupoidea, Subfam. Telenominae). Ann. Mag. Nat. Hist., ser. 10, vol. 17, pp. 558-564, 3 figs.

    1937. Some Asiatic Telenominae (Hym., Proctotrupoidea). Ann. Mag. Nat. Hist., ser. 10, vol. 20, pp. 444-475, 12 figs.

    1938. Three new Telenominae. Ann. Mag. Nat. Hist., ser. 11, vol. 1, pp. 278-286, 5 figs.

PECK, O.

    1937. The male genitalia in the Hymenoptera (Insecta), especially the family Ichneumonidae. Canadian Journ. Research, sec. D, vol. 15, pp. 221-274, 158 figs.

PRATT, H. D.

    1939. Studies on the Ichneumonidae of New England, II. Male genitalia of the subfamily Ichneumoninae. Ann. Ent. Soc. America, vol. 32, pp. 727-742, 3 pls.

    1940. Studies on the Ichneumonidae of New England, I. The external morphology of Arotes amoenus Cresson. Journ. New York Ent. Soc., vol. 48, pp. 155-193, pls. 5-7.

PRUTHI, H. S.
    1924. On the postembryonic development and homologies of the male geni-
        talia of Tenebrio molitor L. (Coleoptera). Proc. Zool. Soc. London
        for 1924, pp. 857-868, pls. 1-3.
    1924a. The development of the male genitalia of Homoptera, with preliminary
        remarks on the nature of these organs in other insects. Quart.
        Journ. Micr. Sci., vol. 69, pp. 59-96, pl. 5.
    1925. The morphology of the male genitalia in Rhynchota. Trans. Ent.
        Soc. London for 1925, pp. 127-267, pls. 6-32.
QADRI, M. A. H.
    1940. On the development of the genitalia and their ducts of orthopteroid
        insects. Trans. Roy. Ent. Soc. London, vol. 90, pp. 121-175, 7 pls.
RAWAT, B. L.
    1939. Notes on the anatomy of Naucoris cimicoides L. (Hemiptera-Heter-
        optera). Zool. Jahrb., Anat., vol. 65, pp. 535-600, 24 figs.
    1939a. On the habits, metamorphosis and reproductive organs of Naucoris
        .   cimicoides L. Trans. Roy. Ent. Soc. London, vol. 88, pp. 119-138,
        8 figs.
RICHARDS, O. W.
    1939. The British Bethylidae (S. L.) (Hymenoptera). Trans. Roy. Ent.
        Soc. London, vol. 89, pp. 185-344; 111 figs.
ROHWER, S. A., and CUSHMAN, R. A.
    1917. Idiogastra, a new suborder of Hymenoptera with notes on the im-
        mature stages of Oryssus. Proc. Ent. Soc. Washington, vol. 19,
        pp. 89-98, pls. 11, 12.
ROONWAL, M. L.
    1937. Studies on the embryology of the African migratory locust, Locusta
        migratoria migratorioides Reiche and Frm. II. Organogeny. Philos.
        Trans. Roy. Soc. London, ser. B, vol. 227, pp. 175-244, pls. 1-7.
ROSS, H. H.
    1937. A generic classification of the Nearctic sawflies (Hymenoptera,
        Symphyta). Univ. Illinois Bull., vol. 34, No. 94; Illinois Biol.
        Monogr., vol. 15, No. 2, 73 pp., 17 pls.
SANDHOUSE, GRACE A.
    1939. The North American bees of the genus Osmia. Mem. Ent. Soc.
        .   Washington, No. 1, 167 pp., 11 pls.
SCHMIEDEKNECHT, O.
    1882-'84. Apidae Europaeae, vol. 1. Berlin.
SEURAT, L. G.
    1899. Contributiones a l'étude des Hyménoptères entomophages. Ann. Sci.
        Nat., sér. 8, Zool., vol. 10, pp. 1-159, 16 text figs., pls. 1-5.
SHARIF, M.
    1937. On the internal anatomy of the larva of the rat-flea, Nosopsyllus
        fasciatus (Bosc). Philos. Trans. Roy. Soc. London, ser. B, vol. 227,
        pp. 465-538, 82 figs.
SHARP, D., and MUIR, F.
    1912. The comparative anatomy of the male genital tube in Coleoptera.
        Trans. Ent. Soc. London for 1912, pp. 477-642, pls. 43-78.

SNODGRASS, R. E.
    1925. Anatomy and physiology of the honeybee. New York.
    1935. Principles of insect morphology. New York and London.
    1935a. The abdominal mechanisms of a grasshopper. Smithsonian Misc.
        Coll., vol. 94, No. 6, 89 pp., 41 figs.
    1936. Morphology of the insect abdomen. Part III. The male genitalia
        (including arthropods other than insects). Smithsonian Misc. Coll.,
        vol. 95, No. 14, 96 pp., 29 figs.
    1937. The male genitalia of orthopteroid insects. Smithsonian Misc. Coll.,
        vol. 96, No. 5, 107 pp., 42 figs.
THOMSON, C. G.
    1872. Hymenoptera Scandinaviae, vol. 2. Lund.
TOWNES, H. K.
    1938. The Nearctic species of Netelia (Paniscus of authors) and a revision
        of the genera of Neteliini (Hymenoptera, Ichneumonidae). Lloydia,
        vol. 1, pp. 168-231, 8 pls.
VERHOEFF, C.
    1893. Vergleichende Untersuchungen über die Abdominalsegmente und die
        Copulationsorgane der männlichen Coleoptera. Deutsche Ent. Zeit-
        schr. for 1893, pp. 113-170, pls. 1-4.
    1893a. Finden sich für die Laminae basales der männlichen Coleopteren
        Homologa bei Hymenopteren? Zool. Anz., vol. 16, pp. 407-412.
ZANDER, E.
    1900. Beiträge zur Morphologie der männlichen Geschlechtsanhänge der
        Hymenopteren. Zeitschr. wiss. Zool., vol. 67, pp. 461-489, pl. 27.
    1901. Beiträge zur Morphologie der männlichen Geschlechtsanhänge der
        Trichopteren. Zeitschr. wiss. Zool., vol. 70, pp. 192-235, pl. 10.
    1903. Beiträge zur Morphologie der männlichen Geschlechtsanhänge der
        Lepidopteren. Zeitschr. wiss. Zool., vol. 74, pp. 557-615, 15 text
        figs., pl. 29.

ABBREVIATIONS AND LETTERING ON THE PLATE FIGURES

a, subapical tooth of penis valve in *Pteronidea.*
Aed, aedeagus.
An, functional anus, probably secondary opening of invaginated eleventh abdominal segment.
anv, anal vestibule.
ap, apodeme.
apa, apodema aedeagalis, basal apodeme of aedeagus.
aps, apodema sternalis, median apodeme of ninth abdominal sternum.
apt, apodema tergalis, apodeme of ninth tergum.
apv, apodema volsellaris, anterior apodeme of volsellar plate.
atg, acrotergite.
A-V, aedeago-volsellar shaft.

b, "brace" of parameral armature in *Paniscus.*
BR, basal ring, lamina annularis.

c, dorsal rod or plate of aedeagus.
Caul, caulis, or phallobase.
Cer, cercus.
cus, cuspis volsellaris, cuspis (distivolsella).
Cx, coxa.

d, ventral rod of aedeagus.
Dej, ductus ejaculatorius.
dig, digitus volsellaris, digitus.

e, basal process of aedeagal apodeme (ergot).
Enph, endophallus.
Epm, epimeron.
Eps, episternum.

f, parameral spine.

g, dorsal apodeme of volsellar plate in Vespidae.
gc, gonocondyle.
GC, genital chamber.

h, aedeagal hook in *Berecyntus bakeri.*

i, plate between bases of volsellae.

j, sclerotic bridge uniting bases of volsellae.

k, basal hinge of aedeagus on parameral plate in *Vespa.*

l, subanal plate of segment *X.*
lp, lamina parameralis, parameral plate of caulis (basiparamere).

69

lr, lateral basal ramus of digitus.
ltg, laterotergite, or laterotergal area.
lv, lamina volsellaris, volsellar plate of caulis (basivolsella).

m, dorsal plate at base of penis in Apoidea uniting with bases of sagittae.
mcl, muscle.
mr, mesal basal ramus of digitus.

n, plate in dorsal wall of penis ("spatha") in Apoidea.
N_2, mesonotum.
N_3, metanotum.

o, ventral lobe of parameral plate.

p, "pad" of parameral armature in *Paniscus.*
pa, parapenial lobe (dorsal) of parameral plate.
pen, penis, median lobe of aedeagus in Apoidea.
Pgs, pygostyle.
Phl, phallus.
Phtr, phallotreme (aperture of endophallus).
Pl, pleuron.
PlS, pleural suture.
Pmr, paramere.
PN_2, postnotum of mesothorax.
Ptgr, proctiger.
pv, penis valve, lamina aedeagalis.

q, dorsal lamella of paramere in Bombidae.

r, ventral lamella of paramere in Bombidae.
Rect, rectum.

s, basal lobe of sagitta in Meliponidae.
S, sternum.
sag, sagitta, lateral lobe of aedeagus in Apoidea (penis valve).
Sp, spiracle.

t, expanded anterior end of ninth-segment tergite.
T, tergum.

u, process of ninth abdominal sternum in *Apis* adjoining parameral plate, or united with the latter.

v, retractile vesicle, or cupping disk (ventouse), of paramere.
Vd, vas deferens.
vol, volsellar lobe.
Vol, volsella.
vr, volsellar ridge, carina volsellaris.

w, membranous dorsal lip of phallotreme in *Apis.*

x, lateral sclerite of penis in Apoidea.

I-X, abdominal segments, including propodeum.

EXPLANATION OF PLATES

PLATE I

CHALASTOGASTRA

A, *Macroxyela ferruginea* (Say) (Xyelidae), phallus, dorsal.

B, same, phallus, ventral.

C, same, terminal segments, dorsal.

D, same, aedeagus, dorsal.

E, same, right parameral plate, paramere, and volsella, mesal.

F, *Xyela minor* Norton (Xyelidae), abdomen, dorsal.

G, same, abdomen, ventral.

H, same, phallus, lower side (dorsal).

I, same, phallus, upper side (ventral).

J, same, aedeagus, lateral.

K, same, right volsella, dorsal.

L, same, terminal segments, dorsal.

M, same, paramere, showing muscle (*17*) of cupping disk (*v*).

N, *Gilpinia polytoma* (Htg.) (Tenthredinoidea), abdomen and base of thorax.

O, *Neodiprion sertifer* (Geoff.) (Tenthredinoidea), terminal segments, dorsal.

P, *Gilpinia polytoma* (Htg.), terminal segments, dorsal.

Q, *Neodiprion sertifer* (Geoff.), volsella.

R, *Gilpinia polytoma* (Htg.), phallus, lower side (dorsal).

S, same, phallus, upper side (ventral).

PLATE 2

CHALASTOGASTRA

A, *Pteronidea ribesii* (Scop.) (Tenthredinoidea), abdomen and base of thorax, lateral.

B, same, terminal segments, lateral.

C, same, phallus, under side (dorsal).

D, same, phallus, upper side (ventral).

E, same, phallus, lateral.

F, same, right penis valve and muscles, mesal.

G, same, left penis valve, lateral.

H, same, right parameral plate, paramere, and volsella, mesal.

I, same, left volsella, lateral.

J, *Acantholyda erythrocephala* (L.) (Pamphiliidae), end of abdomen, dorsal.

K, same, end of abdomen, ventral.

L, same, terminal segments, dorsal.

M, same, phallus, dorsal.

N, same, phallus, ventral.

O, same, aedeagus, ventral.

P, *Xiphydria maculata* (Say) (Xiphydriidae), end of abdomen, ventral.

Q, same, terminal segments, dorsal.

R, same, left volsella, dorsal.

S, *Acantholyda erythrocephala* (L.) (Pamphiliidae), terminal lobes of left volsella, dorsal.

PLATE 3

CHALASTOGASTRA

A, *Sirex abbottii* Kirby (Siricidae), end of abdomen, dorsal.

B, same, end of abdomen, ventral.

C, same, terminal segments, dorsal.

D, same, terminal lobes of left volsella, dorsal.

E, same, aedeagus, lateral.

F, *Xiphydria maculata* (Say) (Xiphydriidae), aedeagus, lateral.

G, *Cephus cinctus* Nort. (Cephoidea), terminal lobes of right volsella, ventral.

H, *Sirex abbottii* Kirby (Siricidae), phallus, dorsal.

I, same, phallus, ventral.

J, *Xiphydria maculata* (Say) (Xiphydriidae), phallus, dorsal.

K, same, phallus, ventral.

L, *Cephus cinctus* Nort. (Cephoidea), posterior part of thorax and base of abdomen, lateral.

M, same, terminal segments, lateral.

N, same, terminal segments, dorsal.

O, same, phallus, dorsal.

P, same, phallus, ventral.

Q, *Trachelus tabidus* (F.) (Cephoidea), phallus, dorsal.

R, same, phallus, ventral.

S, same, end of abdomen, lateral.

T, *Cephus cinctus* Nort., aedeagus, ventral.

PLATE 4

CHALASTOGASTRA

A, *Hartigia trimaculata* (Say) (Cephoidea), phallus, dorsal.

B, same, phallus, ventral.

C, same, left volsella, dorsal.

D, *Orussus sayi* Westw. (Orussidae), left volsella, ventral.

E, same, left volsella, laterodorsal.

F, same, abdomen and base of thorax, lateral.

G, same, terminal segments, dorsal.

H, same, aedeagus, ventral.

I, same, phallus, dorsal.

J, same, phallus, ventral.

ICHNEUMONOIDEA

K, *Megarhyssa lunator* (F.) (Ichneumonidae), phallus, dorsal.

L, same, phallus, ventral.

M, *Ichneumon irritator* F. (Ichneumonidae), terminal segments, dorsal.

N, *Megarhyssa lunator* (F.), end of abdomen, lateral, anal vesicle everted.

O, same, terminal segments, lateral.

P, same, terminal segments, dorsal.
Q, same, ninth abdominal sternum.
R, same, right parameral plate, paramere, and volsella, mesal.
S, same, right volsella, mesal.
T, same, left volsella, lateral.
U, same, aedeagus, ventral.

PLATE 5

ICHNEUMONOIDEA

A, *Protichneumon grandis* (Brullé) (Ichneumonidae), abdomen, lateral.
B, same, end of abdomen, ventral.
C, same, terminal segments, ventral.
D, same, phallus, dorsal.
E, same, phallus, ventral.
F, same, aedeagus, lateral.
G, same, right parameral plate, paramere, and volsella, mesal.
H, same, right volsella and muscles, mesal.
I, same, aedeagus, ventral.
J, *Therion morio* (F.) (Ichneumonidae), aedeagus, lateral.
K, same, ninth abdominal sternum.
L, same, abdomen, lateral.
M, same, phallus, dorsal.
N, same, phallus, ventral.
O, same, ninth abdominal segment and phallus, lateral.
P, same, right volsella, mesal.
Q, *Trogus vulpinus* (Grav.) (Ichneumonidae), end of abdomen, lateral.
R, same, terminal segments and phallus, lateral.
S, same, ninth abdominal sternum.
T, same, terminal segments, ventral.
U, same, phallus, dorsal.
V, same, phallus, ventral.
W, same, aedeagus, ventral.
X, *Megaplectes monticola* (Grav.) (Ichneumonidae), end of abdomen, lateral.
Y, same, right volsella, mesal.
Z, same, phallus, dorsal.
Z', same, phallus, ventral.

PLATE 6

ICHNEUMONOIDEA

A, *Paniscus* sp. 1 (Ichneumonidae), right parameral plate, paramere, and volsella, mesal.
B, *Paniscus* sp. 2, mesal surface of right paramere.
C, *Evania punctata* Brullé (Evaniidae), abdomen, lateral.
D, same, phallus, dorsal.
E, same, phallus, ventral.
F, same, right volsella, ventral.
G, *Helcon pedalis* Cress. (Braconidae), left volsella, ventral.
H, same, abdomen, lateral.

I, same, phallus, dorsal.

J, same, phallus, ventral.

K, *Rogas terminalis* (Cress.) (Braconidae), phallus, dorsal.

L, same, phallus, ventral.

M, *Spathius canadensis* (Ashm.) (Braconidae), abdomen, lateral.

N, same, phallus, dorsal.

O, same, phallus, ventral.

P, *Atanycolus rugosiventris* (Ashm.) (Braconidae), abdomen, lateral.

Q, *Microgaster gelechiae* Riley (Braconidae), abdomen, lateral.

PLATE 7

ICHNEUMONOIDEA

A, *Atanycolus rugosiventris* (Ashm.) (Braconidae), phallus, dorsal.

B, same, phallus, ventral.

C, *Microgaster gelechiae* Riley (Braconidae), phallus, dorsal.

D, same, phallus, ventral.

E, *Atanycolus rugosiventris* (Ashm.), terminal segments, ventral.

F, *Macrocentrus cerasivoranae* Vier. (Braconidae), abdomen, lateral.

G, same, ninth abdominal tergum and tenth segment, ventral.

H, same, phallus, dorsal.

I, same, phallus, ventral.

J, same, aedeagus and volsellae, ventral.

K, *Microgaster gelechiae* Riley, terminal segments, ventral.

L, *Spinaria* sp. (Braconidae), abdomen, lateral.

M, same, abdomen, ventral.

N, same, phallus, dorsal.

O, *Phanerotoma tibialis* (Hald.) (Braconidae), abdomen, lateral.

P, same, phallus, ventral.

Q, *Spinaria* sp., phallus, ventral.

R, *Phanerotoma tibialis* (Hald.), abdomen, ventral.

PLATE 8

ICHNEUMONOIDEA

A, *Chelonus sericeus* (Say) (Braconidae), abdomen, lateral.

B, same, abdomen, ventral.

C, same, terminal segments, ventral.

D, same, phallus, dorsal.

E, same, phallus, ventral.

CHALCIDOIDEA

F, *Berecyntus bakeri* How., propodeum and second segment of abdomen, posterior.

G, same, abdomen and phallus, ventral.

H, same, phallus, ventral.

I, *Callimome* sp., abdomen, lateral.

J, same, last tergal plate of abdomen and pygostyles.

K, same, phallus, ventral.

L, *Callimome sackeni* (Ashm.), phallus, ventral.
M, *Tetrasticus bruchophagi* Gah., phallus, ventral.
N, *Pteromalus puparum* (L.), abdomen, dorsal.
O, same, phallus, ventral.
P, *Tetrasticus bruchophagi* Gah., abdomen, dorsal.
Q, *Leucospis affinis* (Say), abdomen, lateral.
R, same, abdomen, ventral.
S, same, phallus, dorsal.
T, same, phallus, ventral.

PLATE 9

CHALCIDOIDEA

A, *Ormyrus* sp., abdomen, ventral.
B, same, phallus, ventral.
C, *Brachymeria ovata* (Say), abdomen, lateral.
D, *Ormyrus* sp., last tergal plate of abdomen and pygostyles.
E, *Brachymeria ovata* (Say), phallus, ventral.
F, *Cheiropachus colon* (L.), phallus, dorsal.
G, same, phallus, ventral.

CYNIPOIDEA

H, *Ibalia maculipennis* Hald. (Ibaliidae), abdomen, lateral.
I, same, ninth abdominal segment, ventral.
J, same, right half of phallus, mesal.
K, same, phallus, dorsal.
L, same, phallus, ventral.
M, *Diplolepis multispinosus* Gill. (Cynipidae), phallus, ventral.
N, same, volsellar digitus and supporting ridge.
O, same, abdomen, lateral.
P, *Figites quinquelineata* Say (Figitidae), right parameral plate, paramere, and
    volsella, mesal.
Q, same, phallus, dorsal.
R, same, abdomen, lateral.

PLATE 10

SERPHOIDEA

A, *Loboscelidia defecta* Kief., phallus, ventral.
B, same, right parameral plate, paramere, and volsella, mesal.
C, *Serphus florissantensis* Roh., abdomen, lateral.
D, same, phallus, lateral.
E, same, aedeagus and left volsella, lateral.
F, same, phallus, dorsal.
G, same, phallus, ventral.
H, *Pelecinus polyturator* (Dru.), abdomen, lateral.
I, same, terminal segments, lateral.
J, same, aedeagus and left volsella, lateral.
K, same, phallus, dorsal.

L, same, phallus, ventral.

M, *Ashmeadopria* sp., phallus, ventral.

N, *Trichopria cubensis* Fouts, phallus, ventral.

O, *Galesus manilae* Ashm., abdomen, ventral.

P, same, phallus, lateral.

Q, *Scelio calopteni* Riley, abdomen, lateral.

R, same, phallus, ventral.

S, *Sparasion pilosum* Ashm., phallus, ventral.

PLATE 11

FORMICOIDEA

A, *Formica* sp. (*fusca* group) (Formicidae), abdomen, lateral.

B, same, right parameral plate, paramere, and volsella, mesal.

C, same, aedeagus, lateral.

D, same, terminal segments, dorsal.

E, same, ninth abdominal sternum.

F, same, phallus, dorsal.

G, same, phallus, ventral.

H, *Liometopum* sp. (Dolichoderidae), aedeagus, lateral.

I, same, abdomen, lateral.

J, same, terminal segments, dorsal.

K, same, ninth abdominal sternum.

L, same, right parameral plate, paramere, and volsella, mesal.

M, same, phallus, dorsal.

N, same, phallus, ventral.

O, same, right volsella (flattened), ventral.

PLATE 12

FORMICOIDEA

A, *Eciton coccum* (Latr.) (Dorylidae), abdomen, lateral.

B, same, terminal segments, dorsal.

C, same, eighth abdominal sternum.

D, same, phallus, ventral.

E, same, right parameral plate, paramere, and volsella, mesal.

F, same, aedeagus, lateral.

G, same, ninth abdominal sternum.

H, *Paraponera clavata* (F.) (Poneridae), terminal segments, dorsal.

I, same, abdomen, lateral.

J, same, eighth abdominal sternum.

K, same, ninth abdominal sternum.

L, same, phallus, dorsal.

M, same, phallus, ventral.

N, same, right volsella, ventral.

O, same, aedeagus, dorsal.

P, *Pogonomyrmex barbatus* (F. Sm.) (Myrmicidae), abdomen, lateral.

Q, same, terminal segments, dorsal.

R, same, eighth abdominal sternum.

S, same, ninth abdominal sternum.

PLATE 13

FORMICOIDEA

A, *Pogonomyrmex barbatus* (F. Sm.) (Myrmicidae), phallus, dorsal.

B, same, right parameral plate, paramere, and volsella, mesal.

C, same, aedeagus, lateral.

D, *Pseudomyrma gracilis* (F.) (Pseudomyrmidae), abdomen, lateral.

E, same, end of abdomen, ventral.

F, same, terminal segments, dorsal.

G, same, right parameral plate, paramere, and volsella, mesal.

H, same, phallus, dorsal.

I, same, phallus, ventral.

CHRYSIDOIDEA

J, *Chrysis kansensis* Vier., abdomen, lateral.

K, same, ninth abdominal sternum.

L, same, abdomen, ventral.

M, same, phallus, dorsal.

N, same, right volsella, mesal.

O, *Chrysis conica* Brullé, aedeagus, dorsal.

P, *Parnopes edwardsii* (Cress.), aedeagus, ventral.

Q, *Holopyga ventralis* (Say), left parameral plate, paramere, and volsella, lateroventral.

R, *Parnopes edwardsii* (Cress.), phallus, ventral.

PLATE 14

MUTILLOIDEA

A, *Dasymutilla* sp. (Mutillidae), abdomen, lateral.

B, same, terminal segments, lateral.

C, same, aedeagus, lateral.

D, same, phallus, dorsal.

E, same, phallus, ventral.

F, same, right parameral plate, paramere, and volsella, mesal.

G, *Scolia nobilitata* F. (Scoliidae), abdomen, lateral.

H, same, terminal segments and phallus, lateral.

I, same, aedeagus, ventral.

J, same, phallus, dorsal.

K, same, phallus, ventral.

L, same, right parameral plate, paramere, and volsella, mesal.

M, *Myzine quinquecincta* (F.) (Typhiidae), end of abdomen, lateral.

N, same, ninth abdominal tergum, with pygostyles projecting from beneath it.

O, same, ninth abdominal sternum.

P, same, phallus (without basal ring), dorsal.

Q, same, phallus (without basal ring), ventral.

R, same, right volsella, mesal.

S, same, phallus, lateral.

PLATE 15

BETHYLOIDEA

A, *Pristocera armifera* (Say), abdomen, ventral.
B, same, phallus, dorsal.
C, same, phallus, ventral.
D, same, right volsellar lobes, dorsal.
E, *Goniozus hortorum* Brues, phallus, dorsal.
F, same, phallus, ventral (parameres spread).
G, Gonotopodine male of unidentified species, phallus, ventral (parameres spread).

VESPOIDEA

H, *Cryptocheilus unifasciatus* (Say) (Psamocharidae), abdomen, lateral.
I, same, phallus, dorsal.
J, same, seventh and eighth abdominal sterna, dorsal.
K, same, ninth abdominal sternum.
L, same, phallus, ventral (basal ring removed, parameres spread).
M, same, aedeagus, ventral.
N, same, phallus, lateral.
O, same, right paramere, mesal.
P, same, right volsella, mesal.
Q, same, left volsella, lateral.

PLATE 16

VESPOIDEA

A, *Monobia quadridens* (L.) (Eumenidae), phallus, dorsal.
B, same, phallus, ventral.
C, same, eighth and ninth abdominal sterna, ventral.
D, same, aedeagus, ventral.
E, *Odynerus* sp. (Eumenidae), abdomen, lateral.
F, same, eighth and ninth abdominal sterna, ventral.
G, same, aedeagus, dorsal.
H, same, phallus, ventral.
I, *Polistes canadensis annularis* (L.) (Vespidae), abdomen, lateral.
J, same, right parameral plate, paramere, and volsella, dorsal (semidiagrammatic).
K, same, phallus, lateral.
L, same, right parameral plate, paramere, and volsella, mesal.
M, same, aedeagus, lateral.
N, same, digitus of right volsella, removed from volsellar plate (O) as indicated by arrows.
O, same, right volsellar plate, mesal.
P, same, eighth and ninth abdominal sterna, ventral.

C, same, ninth abdominal segment, lateral.

D, same, aedeagus, right parameral plate, paramere, and volsella, mesal.

E, same, phallus, dorsal.

F, same, phallus, ventral.

G, same, ninth abdominal sternum.

H, *Microbembex monodonta* (Say), ninth abdominal sternum.

I, *Bicyrtes ventralis* (Say), tenth abdominal segment, ventral.

J, same, ninth abdominal sternum.

K, same, phallus, dorsal.

L, same, volsellae, ventral.

M, *Bembix spinolae* Lep., ninth abdominal sternum.

N, same, tenth abdominal segment, ventral.

O, same, phallus, ventral.

P, same, volsellae, ventral.

Q, *Microbembex monodonta* (Say), abdomen, lateral.

R, same, phallus, lateral.

Plate 20

Sphecoidea

A, *Microbembex monodonta* (Say), aedeagus, dorsal.

B, same, right volsella, mesal.

C, *Philanthus gibbosus* (F.), right volsella, mesal.

D, same, ninth abdominal sternum.

E, same, phallus, dorsal.

F, *Alysson oppositus* Say, eighth abdominal sternum.

G, same, ninth abdominal sternum.

H, same, phallus, dorsal.

I, *Zanysson texanus* (Cress.), ninth abdominal segment, ventral.

J, same, phallus, ventral.

K, same, aedeagus, dorsal.

L, *Astata unicolor* Say, phallus, ventral.

M, same, ninth abdominal sternum.

N, *Larra analis* F., end of abdomen, ventral.

O, *Crabro interruptus* (Lep.), end of abdomen, ventral.

P, *Larra analis* F., phallus, lateral.

Q, same, phallus, ventral.

R, *Crabro interruptus* (Lep.), phallus, ventral.

Plate 21

Sphecoidea

A, *Cerceris fumipennis* Say, abdomen, ventral.

B, same, ninth abdominal sternum.

C, same, phallus, lateral.

D, same, aedeagus, lateral.

E, same, volsellae, ventral.

F, *Dolichurus stantoni* (Ashm.), abdomen, lateral.

G, same, phallus, ventral.

H, *Gorytes phaleratus* Say, abdomen, lateral.
I, same, eighth abdominal sternum.
J, same, phallus, ventral.
K, same, ninth abdominal sternum.
L, *Trypoxylon politum* Say, abdomen, lateral.
M, *Trypoxylon frigidum* F. Sm., ninth abdominal sternum.
N, same, phallus, dorsal.
O, same, phallus, ventral.
P, same, ninth abdominal sternum.
Q, *Trypoxylon politum* Say, phallus, ventral.
R, same, phallus, lateral.

PLATE 22

SPHECOIDEA

A, *Rhinopsis canaliculata* (Say), abdomen, lateral.
B, same, ninth abdominal sternum.
C, same, penis valve and volsellar lobes.
D, same, phallus, ventral.
E, *Psen kohli* Fox, abdomen, lateral.
F, same, eighth abdominal sternum.
G, same, aedeagus, lateral.
H, same, right parameral plate, paramere, and volsella, mesal.
I, same, ninth abdominal sternum.
J, same, phallus, ventral.
K, *Ammobia ichneumonea* (L.), abdomen, ventral.
L, same, ninth abdominal sternum.
M, same, ninth abdominal tergum with pygostyles of tenth segment projecting
   from beneath it.
N, same, volsellae, ventral.
O, *Podalonia luctuosa* (F. Sm.), ninth abdominal sternum.
P, same, volsellae, ventral.
Q, *Ammobia ichneumonea* (L.), phallus, dorsal.
R, same, phallus, ventral.
S, *Podalonia luctuosa* (F. Sm.), aedeagus, dorsal.
T, same, phallus, ventral.

PLATE 23

SPHECOIDEA

A, *Sceliphron caementarium* (Drury), abdomen, lateral.
B, same, ninth abdominal sternum.
C, same, tenth abdominal segment and ninth-segment tergites, dorsal.
D, same, phallus, ventral.
E, same, aedeagus, dorsal.
F, same, volsellae, ventral.
G, *Podium naematogastrum* Spin., ninth and tenth abdominal segments, dorsal.
H, *Chalybion cyaneus* (F.), abdomen, lateral.
I, *Podium naematogastrum* Spin., volsellae, ventral.

J, *Chalybion cyaneus* (F.), volsellae, ventral.

K, *Sphex* sp. aedeagus, dorsal.

L, *Chalybion cyaneus* (F.), phallus, dorsal.

M, *Sphex* sp., abdomen, lateral.

N, same, ninth and tenth abdominal segments, posterior.

O, same, phallus, dorsal.

P, same, phallus, ventral.

Q, same, volsellae, ventral.

R, same, volsellae and muscles, dorsal.

PLATE 24

APOIDEA

A, *Andrena crataegi* Robt. (Andrenidae), terminal segments, ventral.

B, same, eighth abdominal sternum.

C, same, ninth abdominal sternum.

D, *Andrena fragilis* F. Sm. (Andrenidae), seventh abdominal sternum.

E, same, eighth abdominal sternum.

F, same, ninth abdominal sternum.

G, same, phallus, dorsal.

H, same, phallus, ventral.

I, same, right parameral plate, paramere, and volsella, mesal.

J, same, volsella.

K, same, aedeagus, lateral.

L, *Andrena crataegi* Robt. (Andrenidae), phallus, dorsal.

M, same, phallus, ventral.

N, same, aedeagus, ventral.

O, same, aedeagus, lateral.

P, same, right volsella, mesal.

Q, *Perdita octomaculata* (Say) (Panurgidae), phallus (basal ring removed), ventral.

R, same, eighth abdominal sternum.

S, same, ninth abdominal sternum.

T, same, aedeagus, dorsal.

U, same, left volsella, lateral.

V, *Halictoides calochorti* Ckll. (Panurgidae), eighth abdominal sternum.

W, same, ninth abdominal sternum.

X, same, right parameral plate, paramere, and volsella, ventral.

Y, same, phallus, dorsal.

PLATE 25

APOIDEA

A, *Hylaeus basalis* (F. Sm.) (Hylaeidae), seventh abdominal sternum.

B, same, eighth abdominal sternum.

C, same, ninth abdominal sternum.

D, *Hylaeus cressoni* (Ckll.) (Hylaeidae), eighth abdominal sternum.

E, same, ninth abdominal sternum.

F, same, eighth and ninth abdominal sterna in relative positions, ventral.

G, *Hylaeus basalis* (F. Sm.), eighth abdominal tergum, ventral, and dorsal wall of genital chamber with ninth tergites and subanal plate.

H, same, phallus, dorsal.

I, same, phallus, ventral.

J, same, right parameral plate and volsella, mesal.

K, same, aedeagus, ventral.

L, *Hylaeus cressoni* (Ckll.), phallus, dorsal.

M, same, phallus, ventral.

N, *Colletes inaequalis* Say (Hylaeidae), eighth abdominal sternum.

O, same, ninth abdominal sternum.

P, *Colletes armatus* Patt. (Hylaeidae), eighth abdominal sternum.

Q, same, ninth abdominal sternum.

R, same, phallus, dorsal.

S, same, right volsella, ventral.

T, *Colletes inaequalis* Say, phallus, dorsal.

U, same, aedeagus, ventral.

V, same, right volsellar lobes, ventral.

PLATE 26

APOIDEA

A, *Macropis ciliata* Patt. (Ctenoplectridae), seventh abdominal sternum.

B, same, eighth abdominal sternum.

C, same, ninth abdominal sternum.

D, same, phallus, dorsal.

E, same, right parameral plate, paramere, and volsella, mesal.

F, same, left volsella with muscles and part of supporting parameral plate, ventral.

G, same, aedeagus, ventral.

H, *Anthophora abrupta* Say (Anthophoridae), seventh abdominal sternum.

I, same, eighth abdominal sternum.

J, same, ninth abdominal sternum.

K, same, phallus, dorsal.

L, same, phallus, ventral.

M, same, aedeagus, dorsal.

N, same, aedeagus, ventral.

O, *Diadasia australis* (Cress.) (Anthophoridae), eighth abdominal sternum.

P, same, ninth abdominal sternum.

Q, same, phallus, dorsal.

R, same, aedeagus, dorsal.

S, *Tetralonia atriventris* (F. Sm.) (Anthophoridae), phallus, dorsal.

T, same, aedeagus, ventral.

U, same, eighth abdominal sternum.

V, same, ninth abdominal sternum.

PLATE 27

APOIDEA

A, *Melissodes* sp. (Anthophoridae), eighth and ninth abdominal sterna in natural relative positions, ventral.

B, same, ninth abdominal sternum.

C, same, phallus, dorsal.

D, same, phallus, ventral.

E, same, aedeagus, ventral.

F, *Nomada bella* Cress. (Nomadidae), eighth abdominal sternum.

G, same, ninth abdominal sternum.

H, same, phallus, dorsal.

I, same, aedeagus, ventral.

J, same, right parameral plate, paramere, and volsella, mesal.

K, *Melecta armata* (Panz.) (Melectidae), eighth abdominal sternum.

L, same, ninth abdominal sternum.

M, same, phallus, dorsal.

N, same, phallus (aedeagus removed), ventral.

O, same, right parameral plate, paramere, and volsella, mesal.

P, same, penis, lateral.

Q, same, aedeagus, lateral.

R, *Crocisa crucifera* Ckll. (Melectidae), eighth abdominal sternum.

S, same, ninth abdominal sternum.

T, same, phallus, dorsal.

U, same, phallus (aedeagus removed), ventral.

V, same, aedeagus, lateral.

PLATE 28

APOIDEA

A, Crocisa crucifera Ckll. (Melectidae), right half of caulis with paramere and volsella (aedeagus removed), mesal.

B, same, right paramere and muscle, mesal.

C, *Triepeolus concavus* (Cress.) (Melectidae), end of abdomen, ventral.

D, same, seventh abdominal sternum.

E, same, eighth abdominal segment and enclosed ninth sternum, ventral.

F, same, eighth abdominal sternum.

G, same, ninth abdominal sternum.

H, same, eighth abdominal tergum and ninth sternum exposed in place by removal of eighth sternum, ventral (compare with E).

I, same, ninth and tenth abdominal segments (phallus removed), ventral.

J, same, phallus, dorsal.

K, same, caulis and parameres (aedeagus removed), dorsal.

L, same, caulis and parameres, ventral.

M, same, aedeagus, dorsal.

N, same, aedeagus, ventral.

O, *Megachile* sp. (Megachilidae), end of abdomen, ventral.

P, same, seventh and eighth abdominal segments, ventral.

Q, same, eighth abdominal segment, ventral.

R, same, ninth abdominal sternum.

S, same, phallus, dorsal.

T, same, phallus, ventral.

PLATE 29

APOIDEA

A, *Coelioxys* sp. (Megachilidae), end of abdomen, ventral.

B, same, seventh abdominal sternum.

C, same, eighth and ninth abdominal segments, with projecting parameres of phallus, ventral.

D, same, aedeagus, ventral.

E, same, phallus, dorsal.

F, same, phallus, ventral

G, *Xylocopa virginica* (L.) (Xylocopidae), eighth, ninth, and tenth abdominal segments, with phallus exposed in genital chamber, ventral.

H, same, eighth abdominal sternum.

I, same, ninth abdominal sternum, and dorsal wall of genital chamber containing tergites of ninth segment and ending with tenth segment.

J, same, phallus, dorsal.

K, same, phallus, ventral.

L, same, aedeagus, dorsal.

M, same, aedeagus, lateral.

N, *Bombus americanorum* (F.) (Bombidae), eighth abdominal sternum.

O, same, ninth and tenth abdominal segments (phallus removed), with margin of eighth tergum, ventral.

P, *Bombus lapidarius* (L.) (Bombidae), phallus, dorsal.

PLATE 30

APOIDEA

A, *Bombus americanorum* (F.) (Bombidae), phallus, dorsal.

B, same, phallus, ventral.

C, same, dorsal bridge uniting basal angles of parameral plates.

D, same, aedeagus, dorsal.

E, same, aedeagus, ventral.

F, same, right parameral plate and paramere, lateral.

G, same, right parameral plate and paramere, mesal.

H, *Trigona testacea cupira* (F. Sm.) (Meliponidae), abdomen, lateral.

I, same, eighth and ninth abdominal sterna, ventral.

J, same, seventh and eighth abdominal terga, with dorsal wall of genital chamber containing ninth tergites, ventral.

K, same, phallus, dorsal.

L, same, phallus, ventral.

M, same, right sagitta of aedeagus, mesal.

N, *Trigona compressa* (Latr.) (Meliponidae), phallus, dorsal.

O, same, phallus, ventral.

PLATE 31

APOIDEA

A, *Melipona favosa* (F.) (Meliponidae), terminal segments exposed by removal of seventh abdominal sternum, showing eighth and ninth sterna in natural relative positions, ventral.

B, same, eighth abdominal sternum.

C, same, ninth abdominal sternum.

D, same, terga of seventh and eighth abdominal segments, and tergites of ninth segment in exposed dorsal wall of genital chamber, ventral.

E, same, phallus, dorsal.

F, same, phallus, ventral.

G, *Apis mellifera* L. (Apidae), end of abdomen, ventral.

H, *Apis indica* F. (Apidae), abdomen, ventral.

I, *Apis florea* F. (Apidae), phallus, dorsal.

J, same, phallus, ventral.

K, *Apis mellifera* L., left tergite and apodeme of ninth abdominal segment.

L, *Apis florea* F., eighth and ninth abdominal sterna, and ninth-segment tergites, ventral.

M, *Apis indica* F., phallus, dorsal.

N, same, sternum and tergites of ninth abdominal segment, with intervening parameral plates of phallus, posterior.

O, *Apis mellifera* L., end of abdomen, posterior, showing phallic plates and phallotreme exposed between tenth segment and ninth sternum.

PLATE 32

APOIDEA

A, *Apis mellifera* L. (Apidae), phallus, dorsal.

B, same, phallus, valve plates (*pv*) separated, dorsal.

C, same, right parameral plate and parameral lobe.

D, same, ectophallus and endophallus, dorsal.

E, same, plates in wall of endophallic bulb.

F, same, end of abdomen of male larva, 18 mm. long, lateral.

G, same, end of abdomen of same larva, ventral.

H, same, primary phallic lobes of larva in "peripodal" pit exposed by removal of outer cuticula.

I, same, phallus of pupa, dorsal.

J, same, phallus of pupa, ventral.

K, same, ventral half of pupal phallus cut horizontally (from Zander, 1900).

L, same, end of abdomen of immature male imago removed from pupal cuticula, lateral.

M, same, end of abdomen of male pupa, posterior.

N, same, right phallic plates of fully matured imago, mesal.

O, same, end of abdomen of immature imago, posterior.

PLATE 33

APOIDEA

A, *Apis mellifera* L., right half of abdominal wall of male, mesal.

B, same, muscles of right half of male abdomen, mesal.

C, same, right halves of eighth and ninth abdominal sterna, and phallic plates of same side, mesal.

D, same, sclerites shown at C, with muscles, mesal.
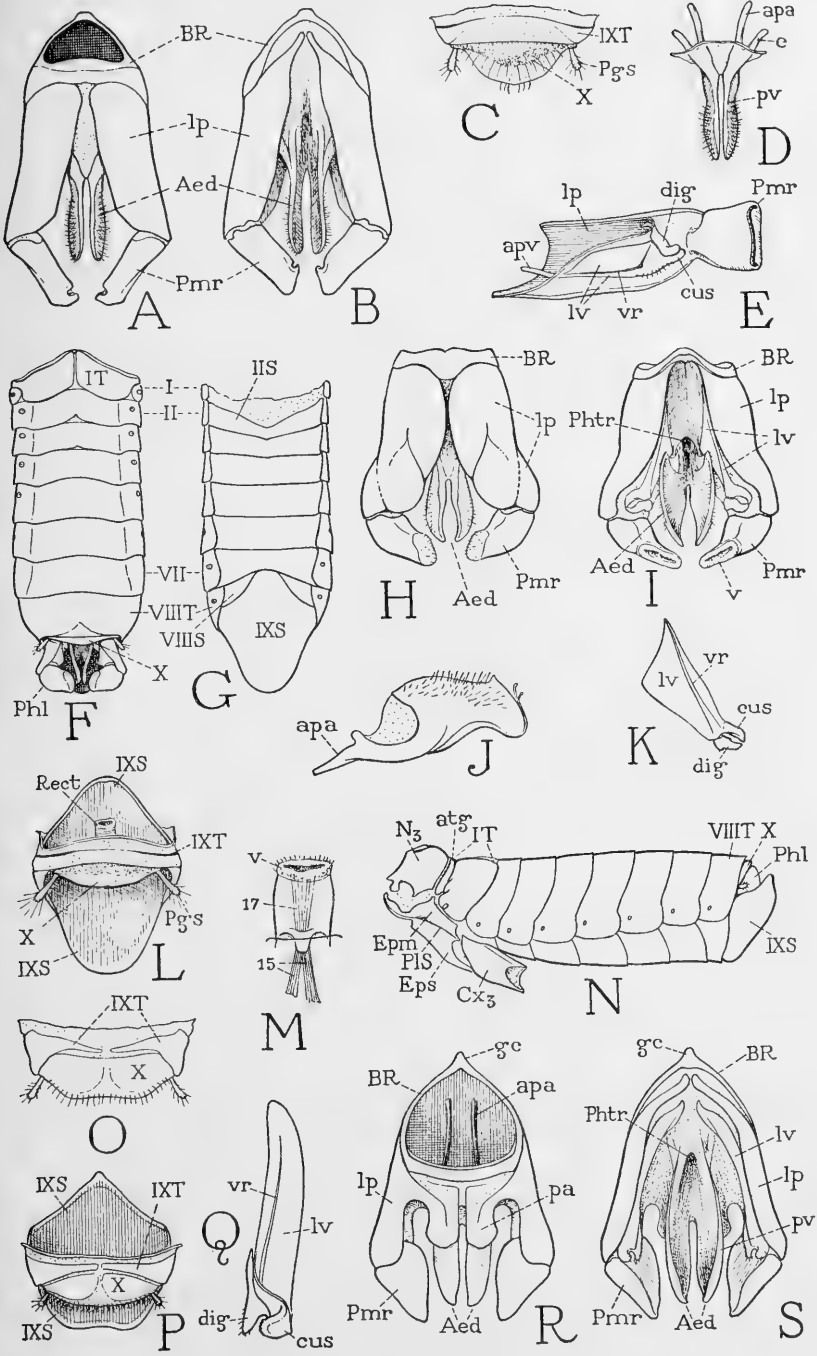
CHALASTOGASTRA

(For explanation, see page 71.)
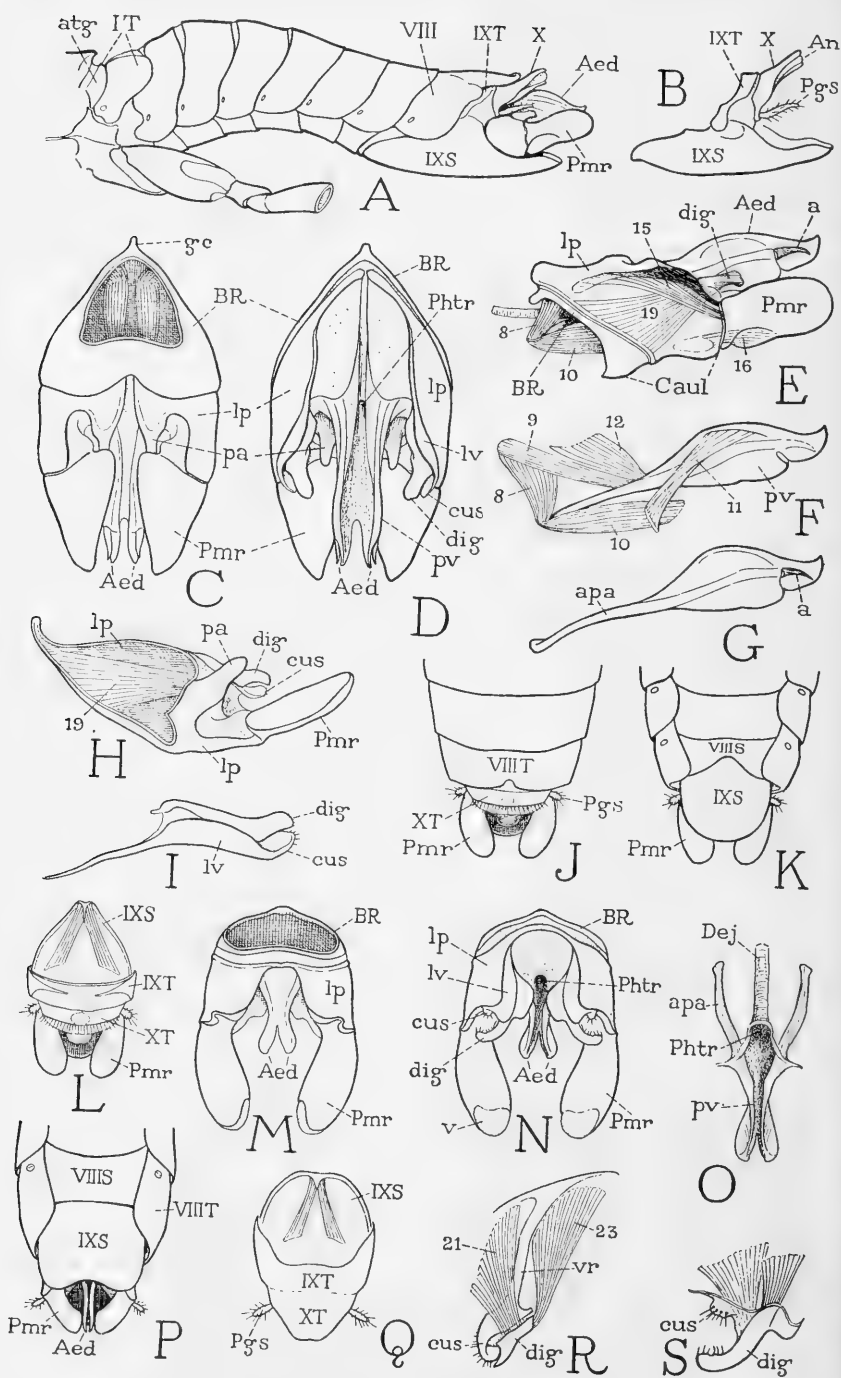
CHALASTOGASTRA

(For explanation, see page 71.)
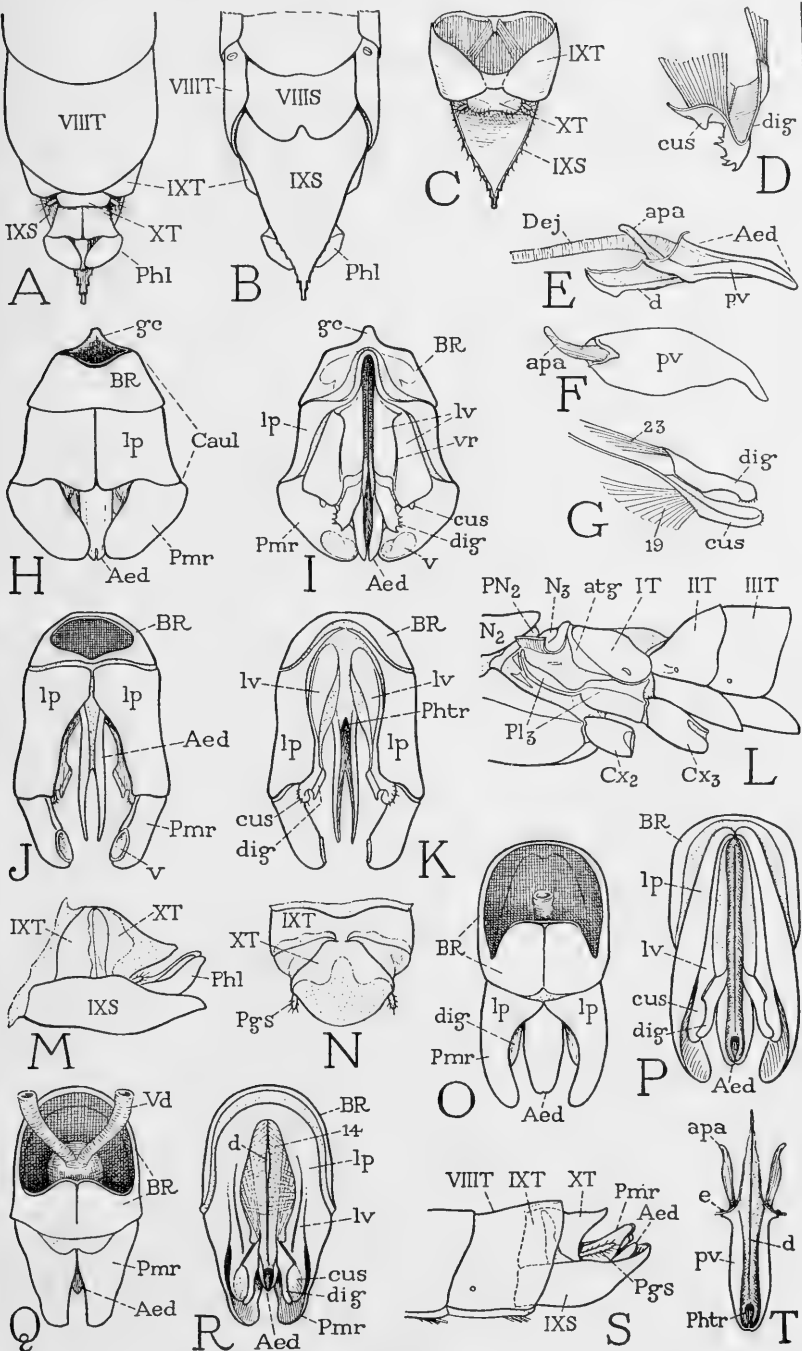
CHALASTOGASTRA

(For explanation, see page 72.)
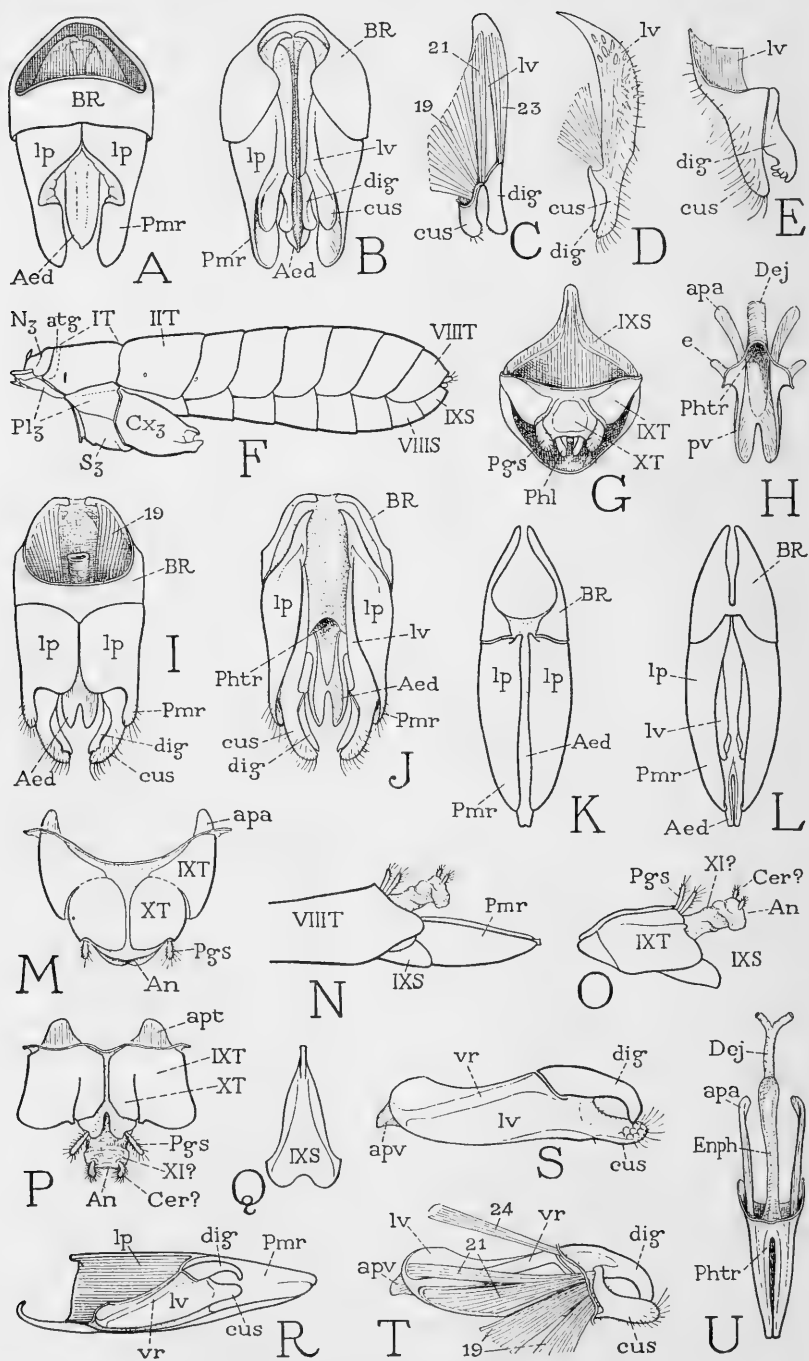
CHALASTOGASTRA. ICHNEUMONOIDEA

(For explanation, see page 72.)
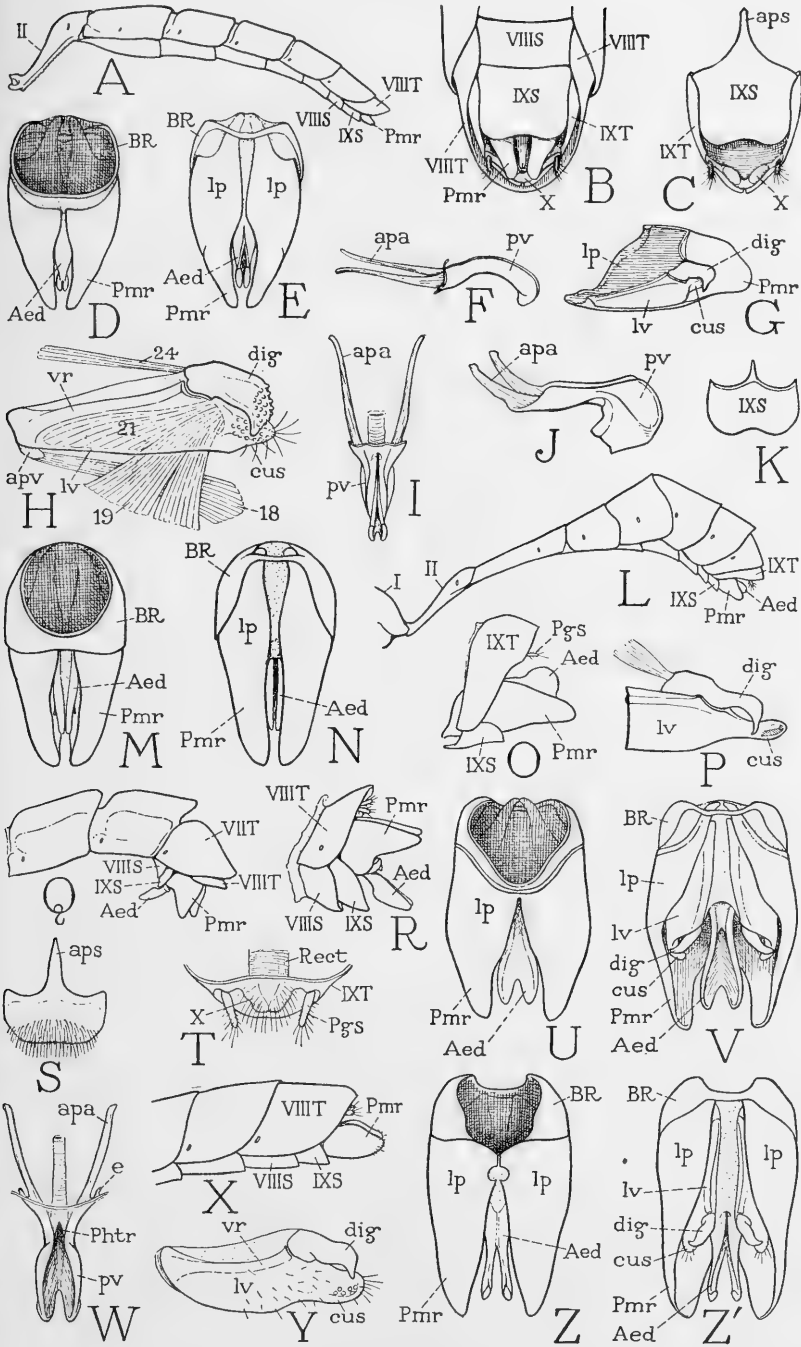
ICHNEUMONOIDEA

(For explanation, see page 73.)
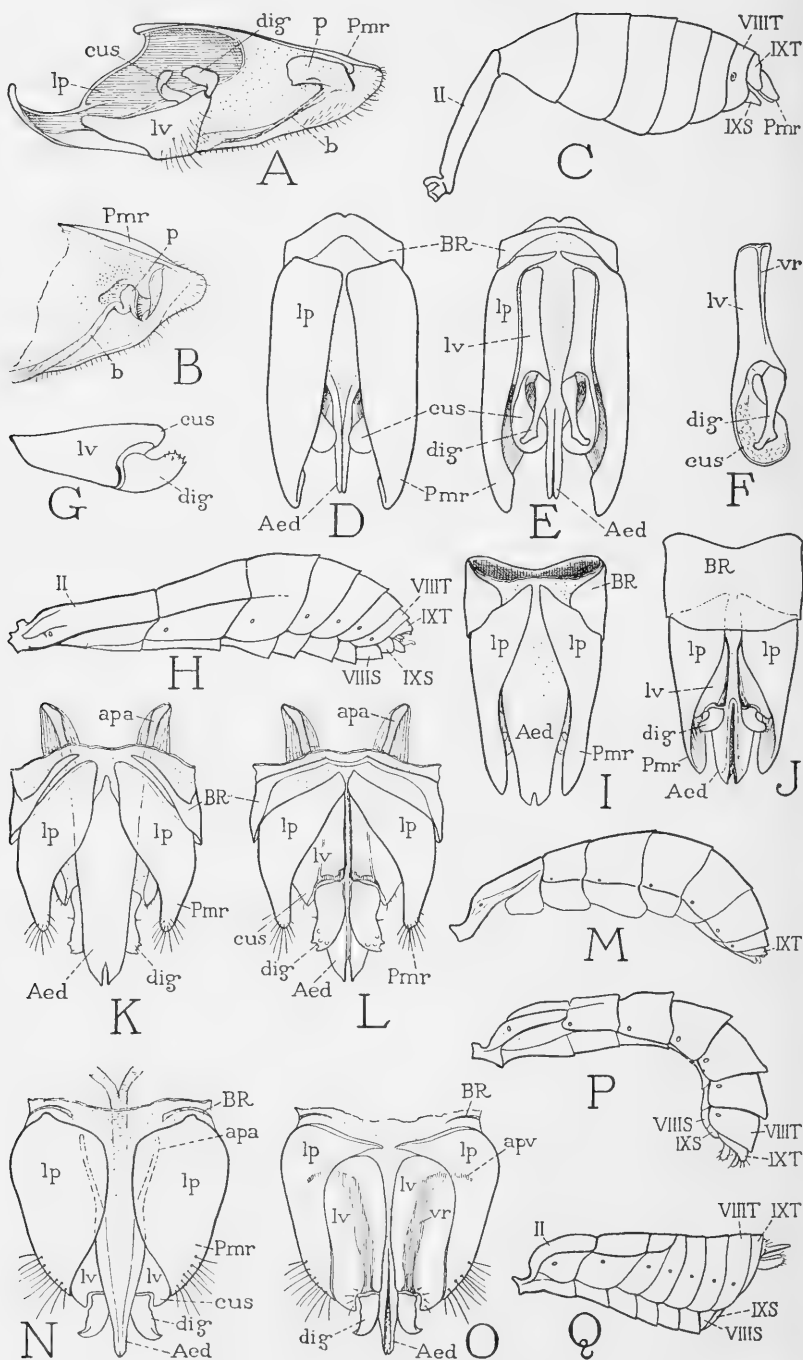
ICHNEUMONOIDEA

(For explanation, see page 73.)
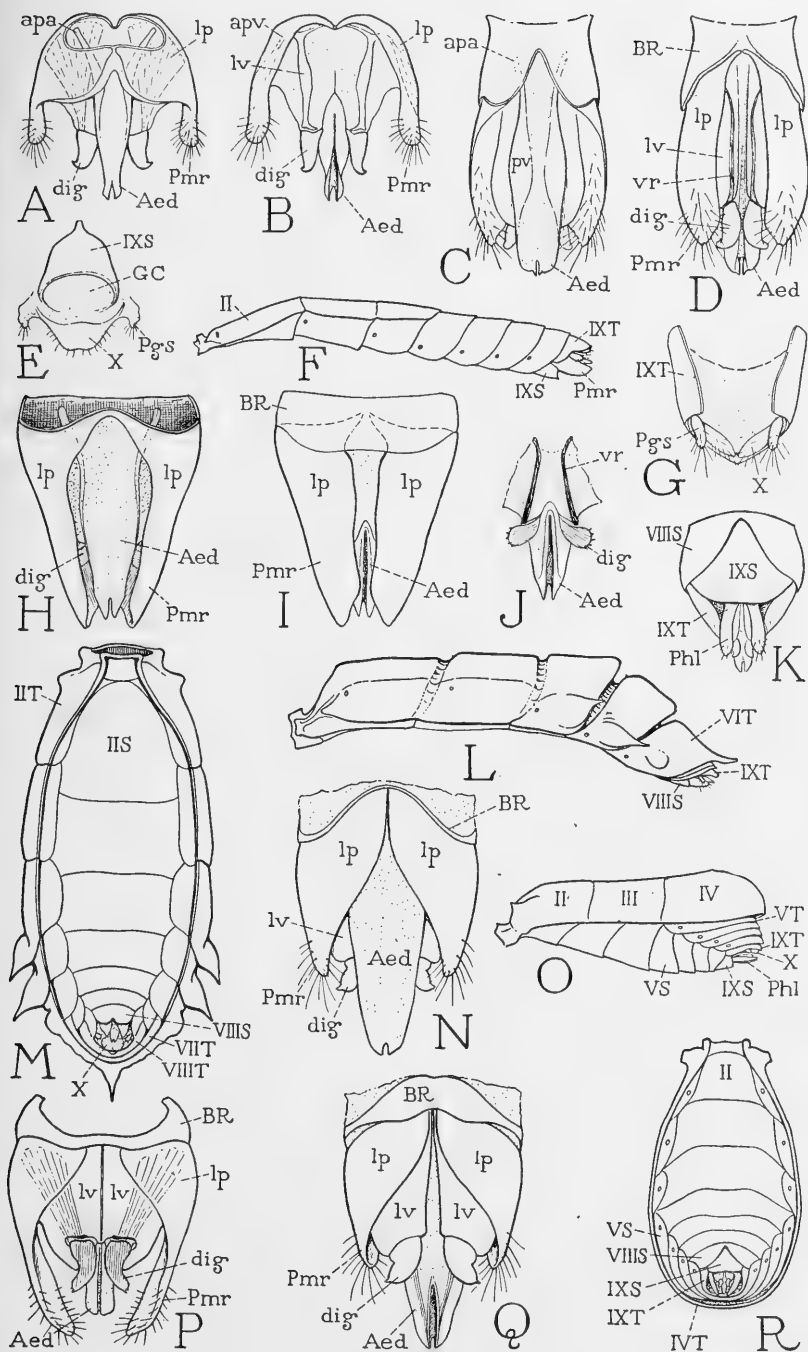
ICHNEUMONOIDEA

(For explanation, see page 74.)
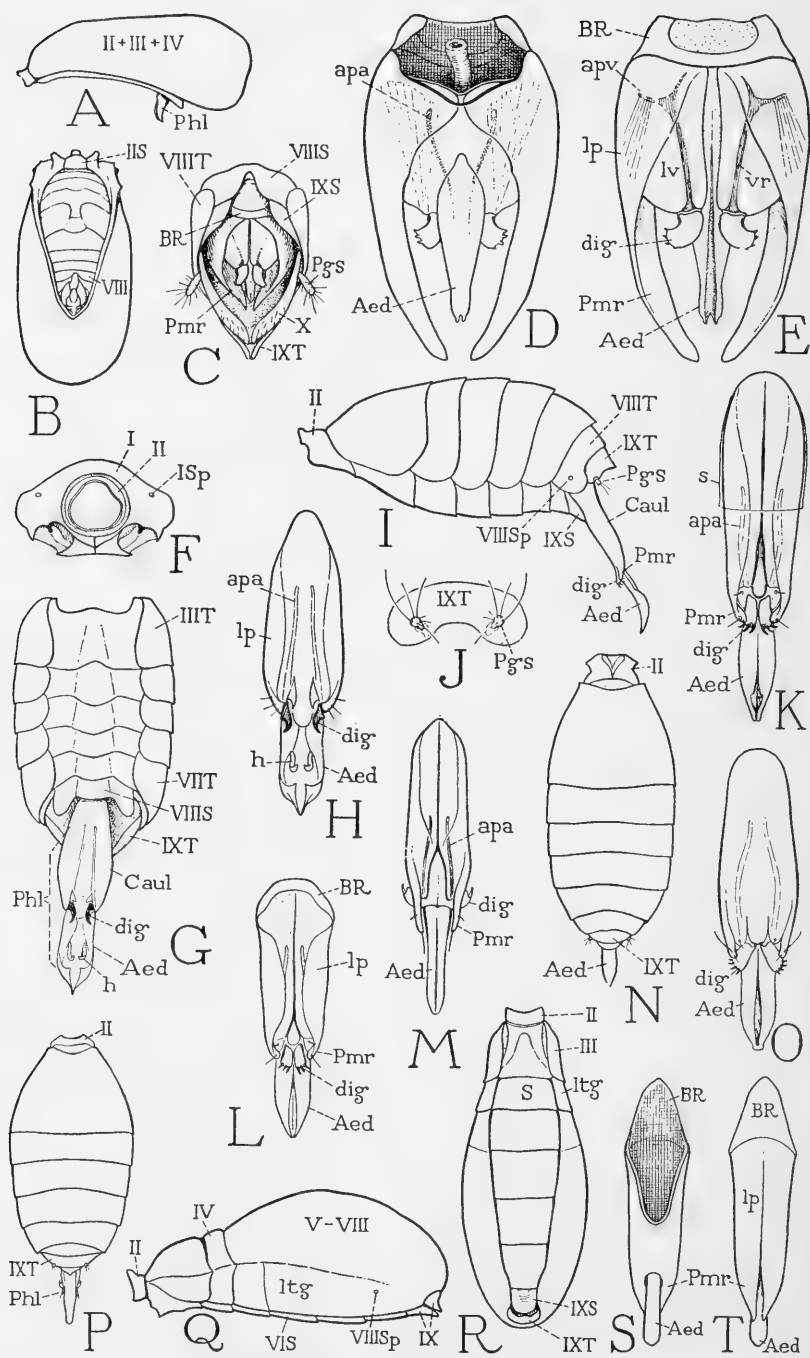
ICHNEUMONOIDEA. CHALCIDOIDEA

(For explanation, see page 74.)
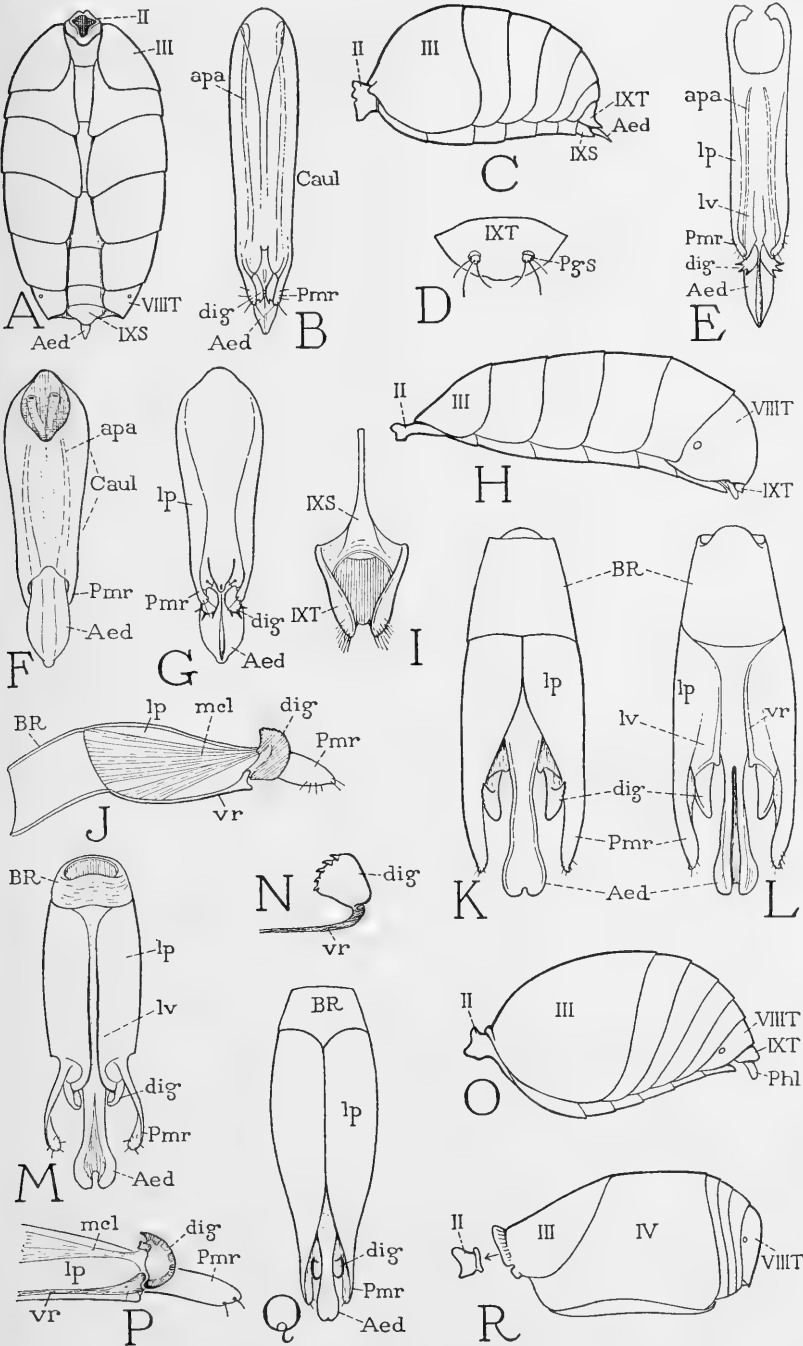
CHALCIDOIDEA. CYNIPOIDEA

(For explanation, see page 75.)
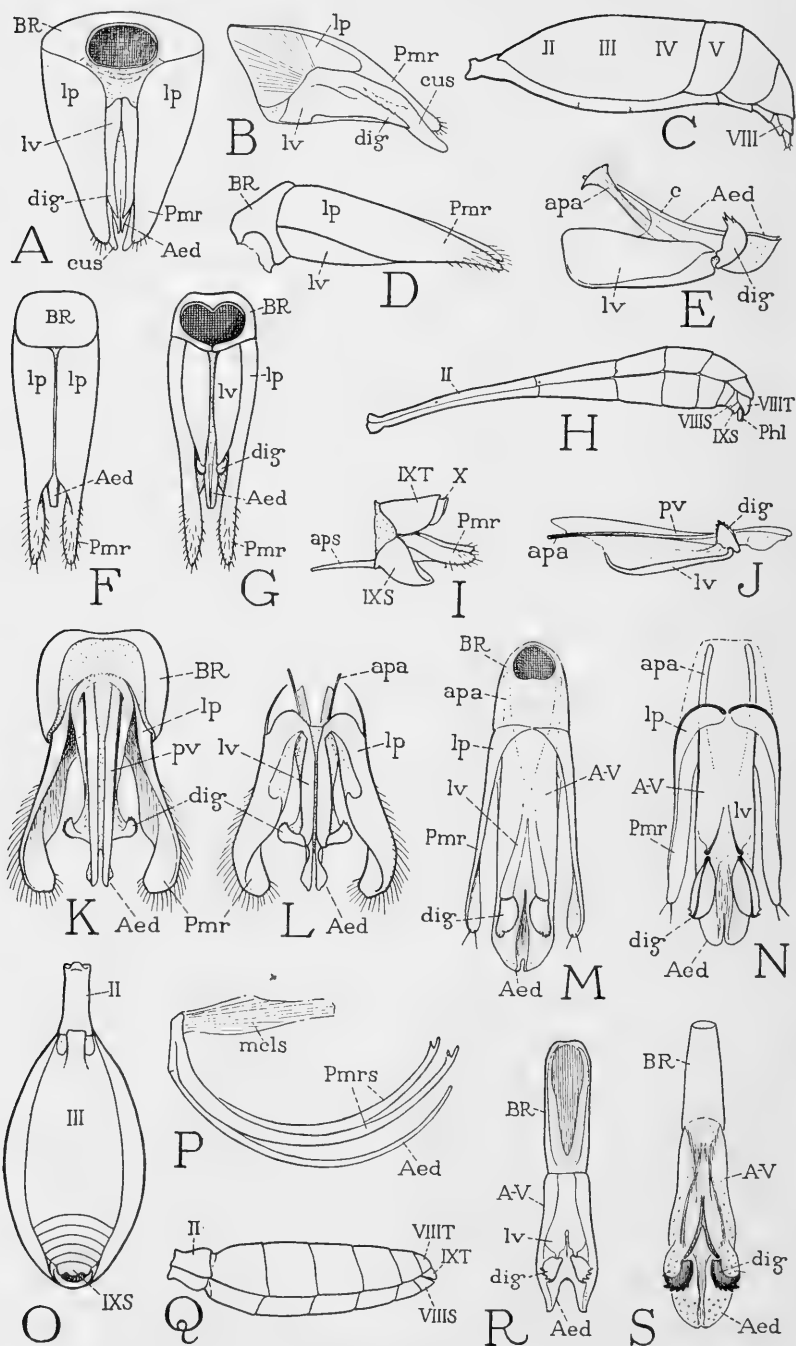
SERPHOIDEA

(For explanation, see page 75.)
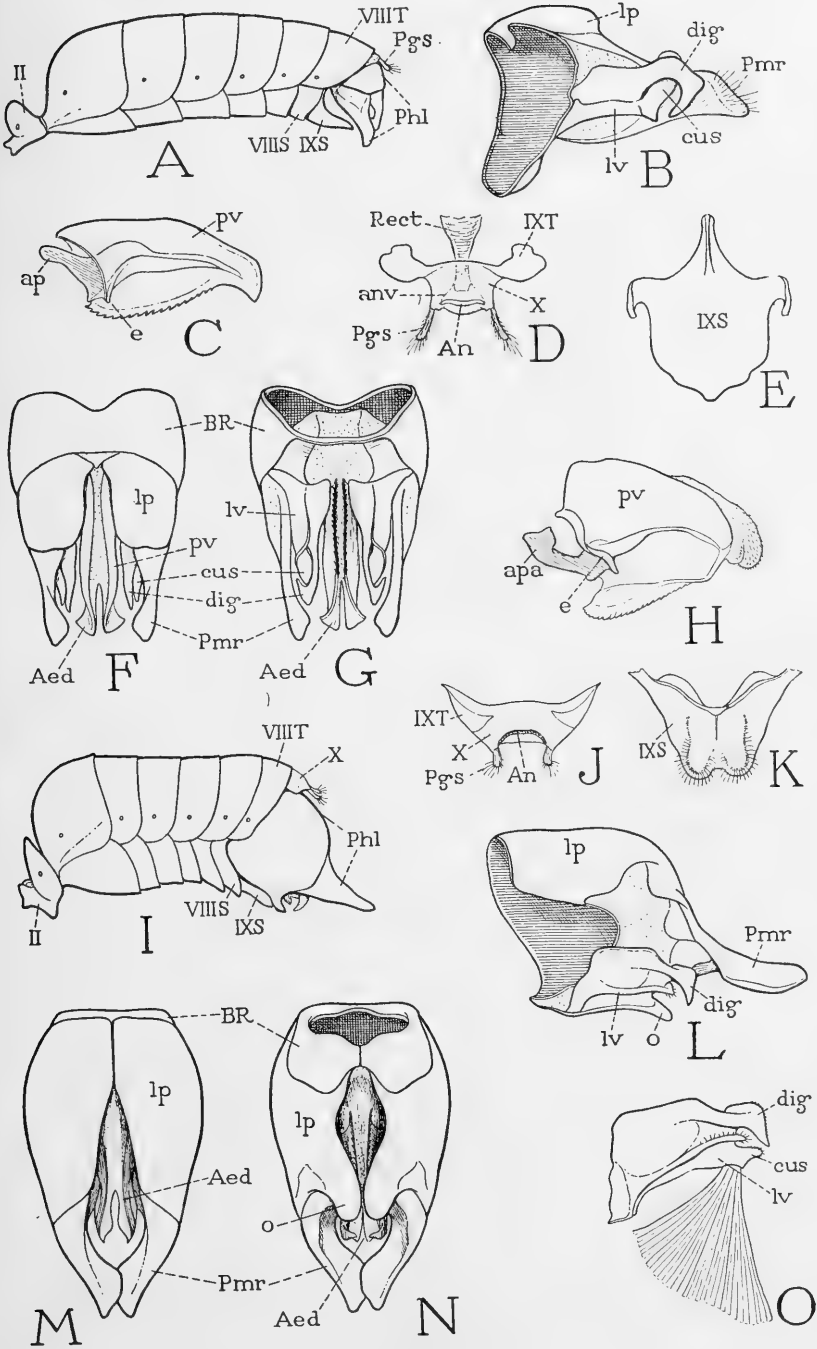
FORMICOIDEA

(For explanation, see page 76.)
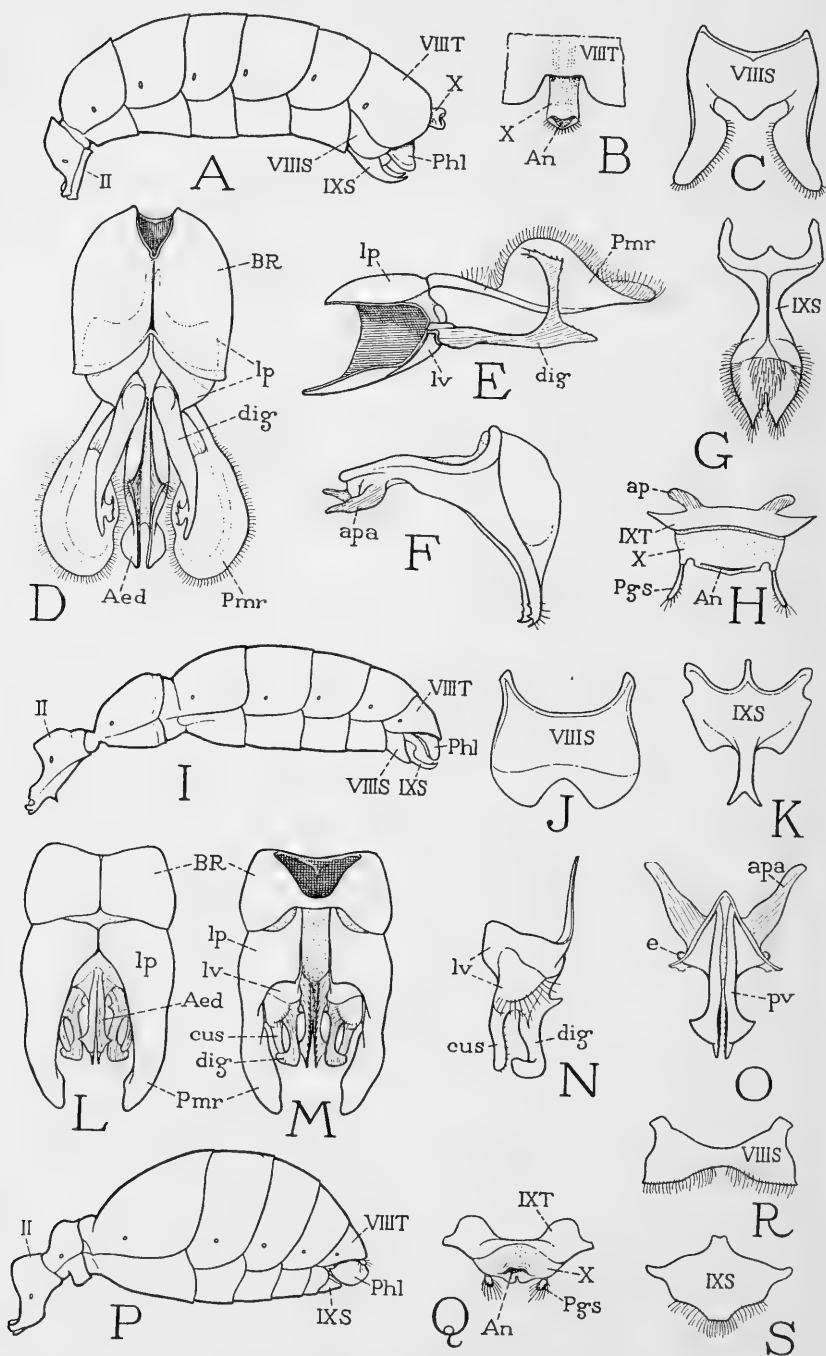
FORMICOIDEA

(For explanation, see page 76.)
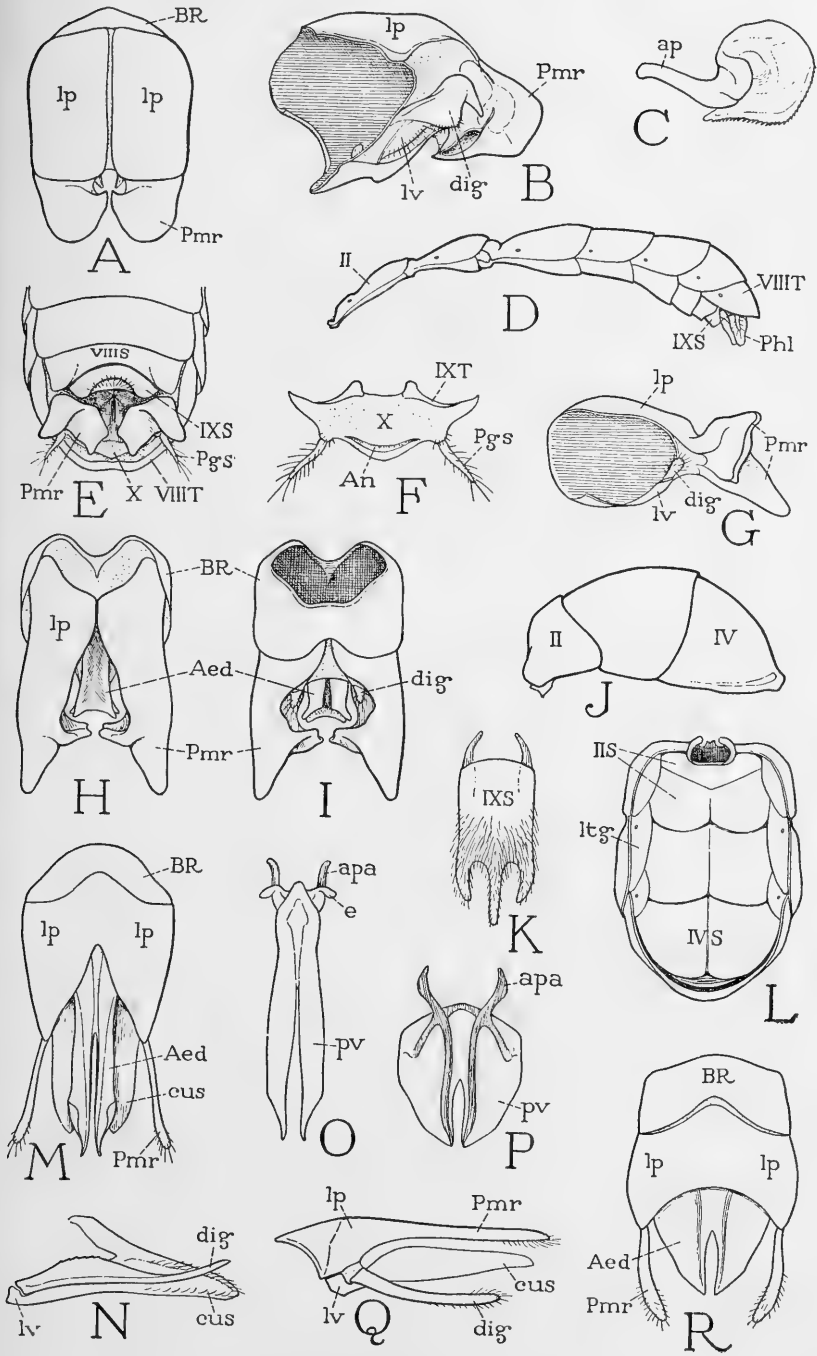
FORMICOIDEA. CHRYSIDOIDEA
(For explanation, see page 77.)
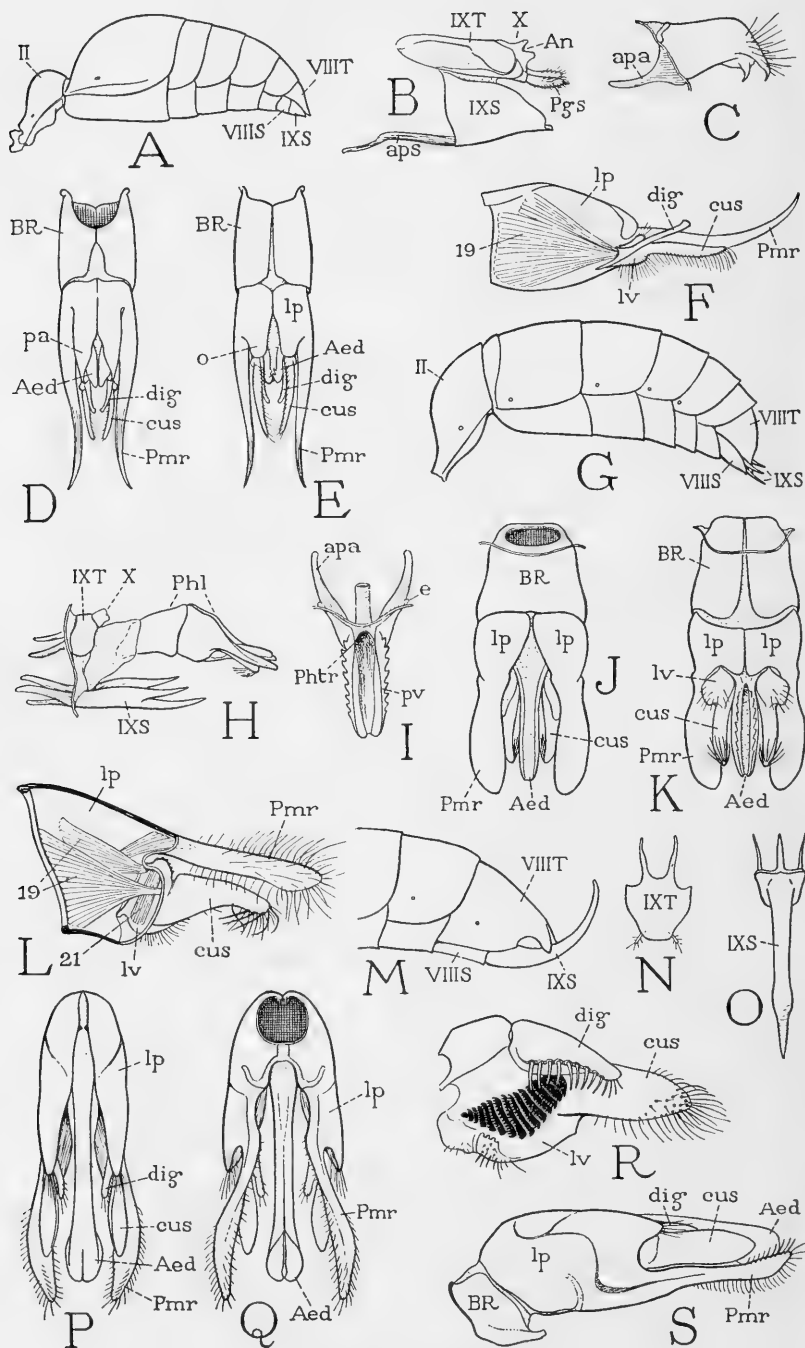
MUTILLOIDEA

(For explanation, see page 77.)
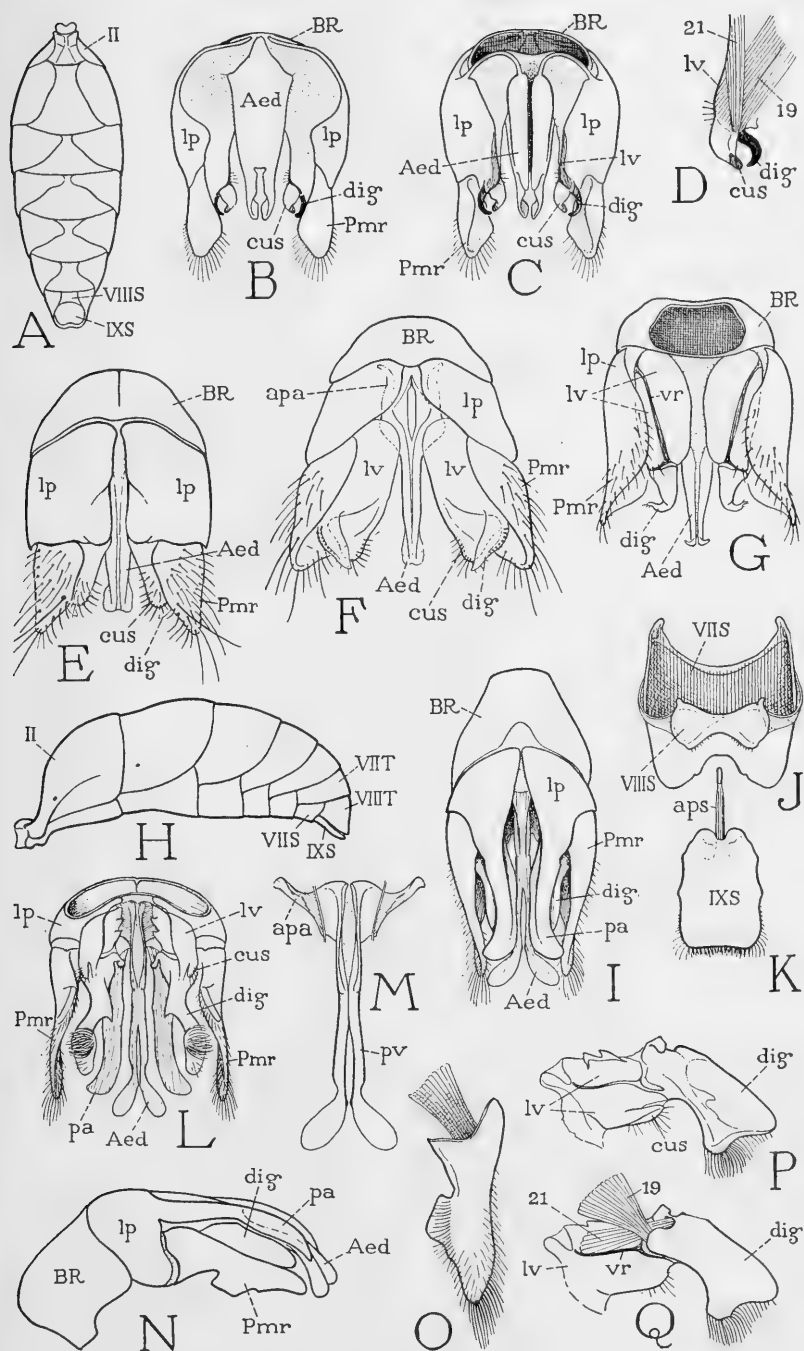
BETHYLOIDEA. VESPOIDEA

(For explanation, see page 78.)
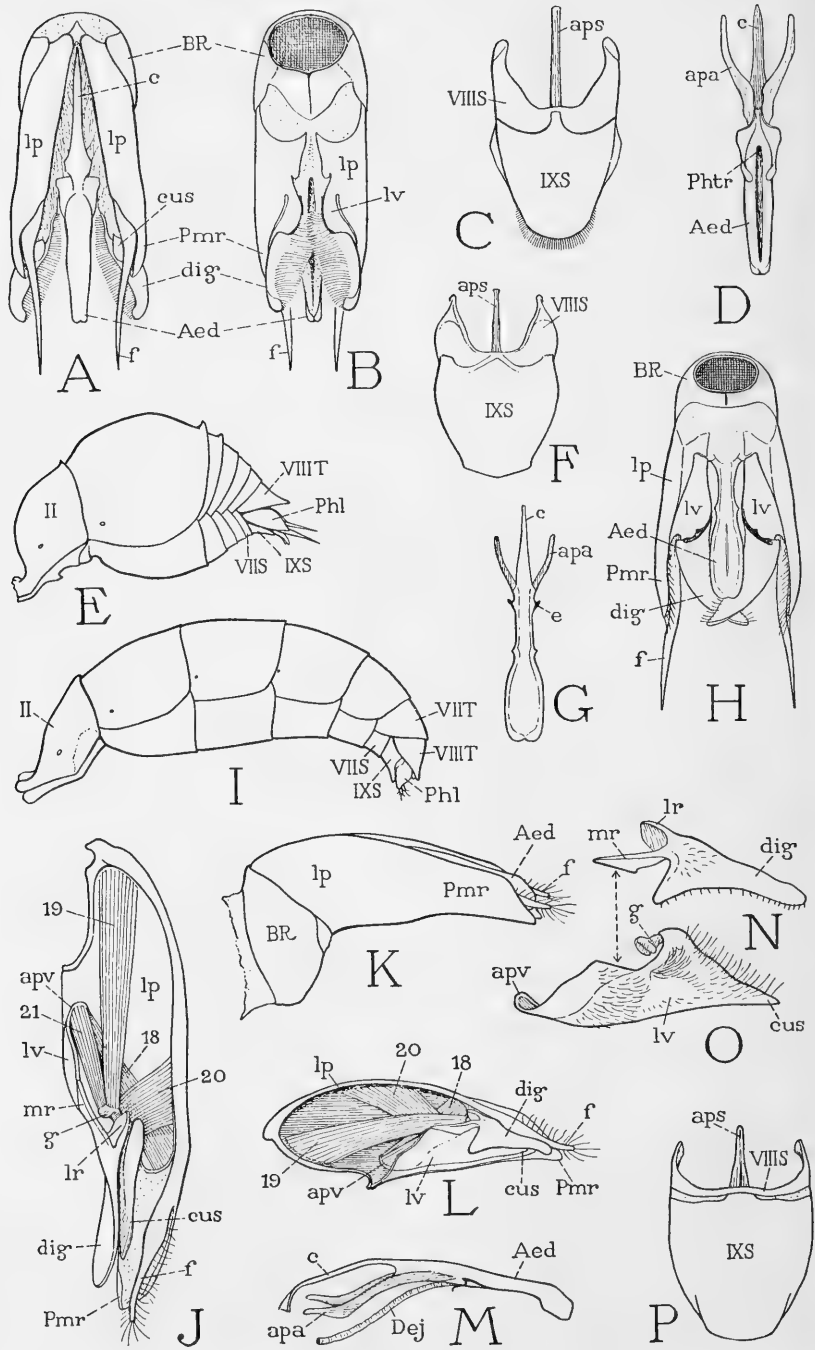
VESPOIDEA

(For explanation, see page 78.)
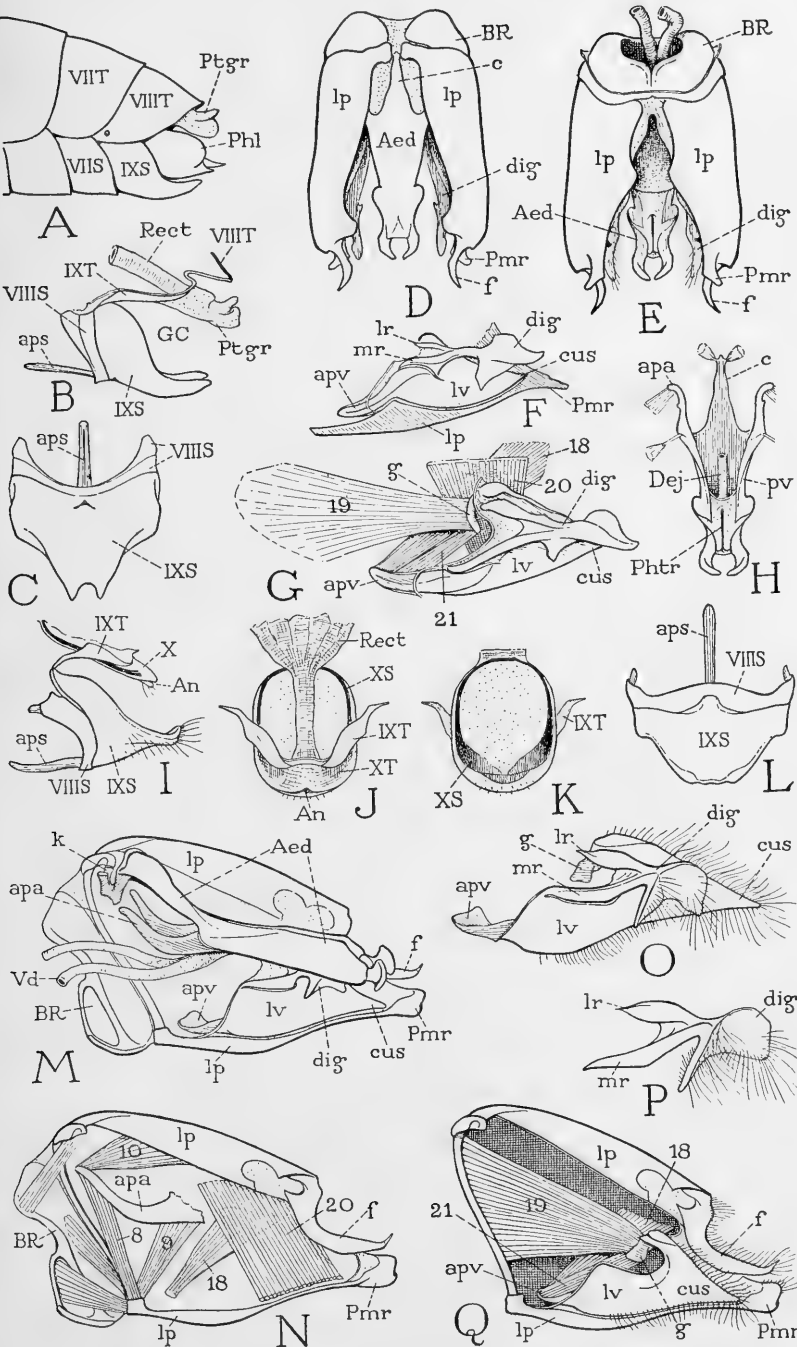
VESPOIDEA

(For explanation, see page 79.)
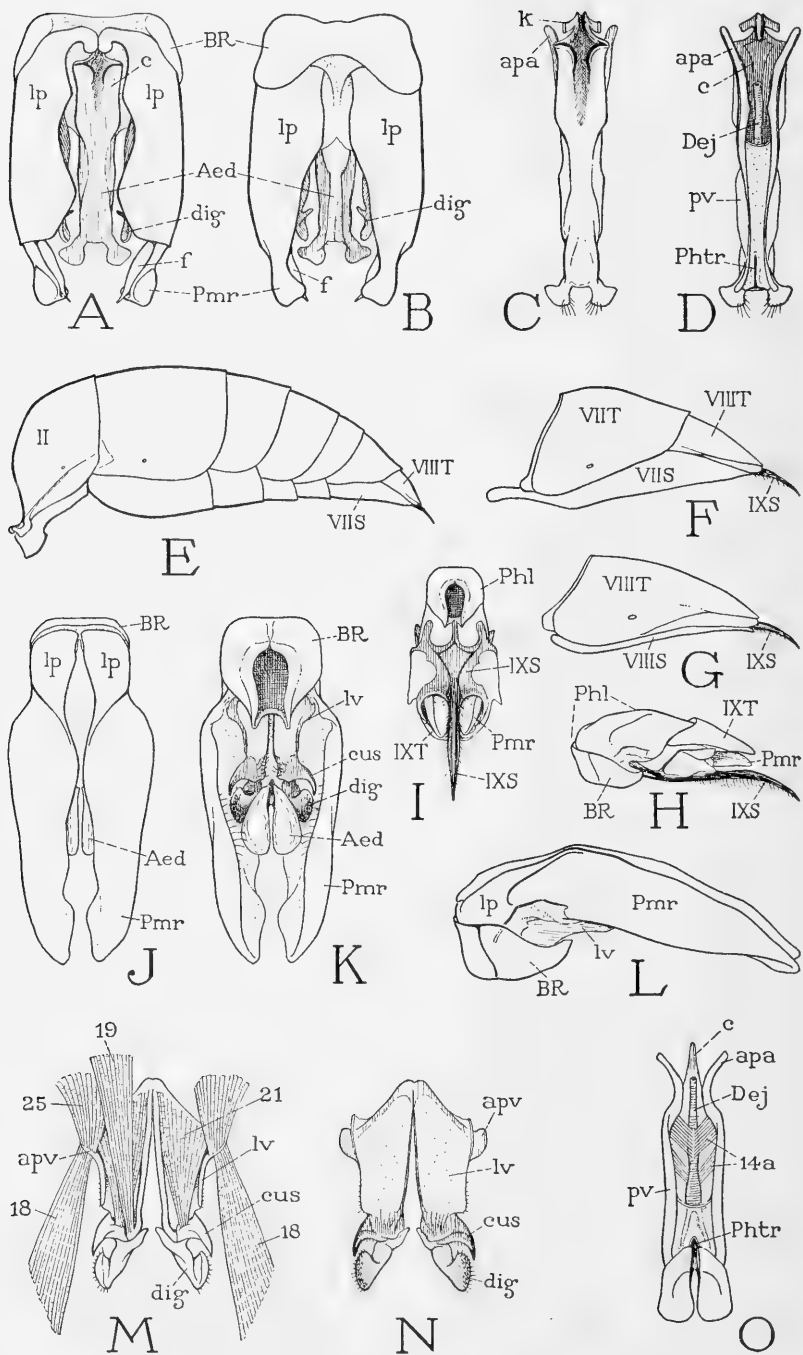
VESPOIDEA. SPHECOIDEA

(For explanation, see page 79.)
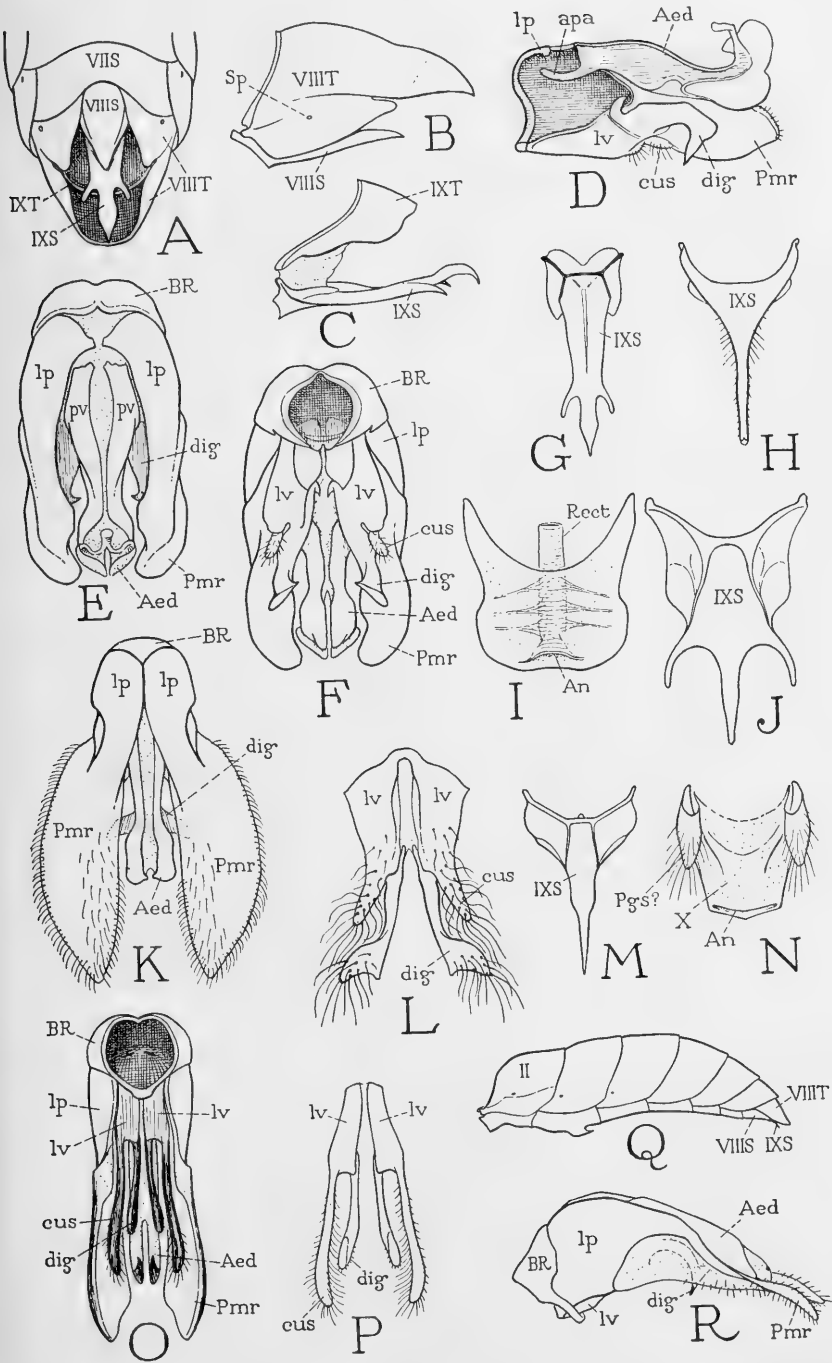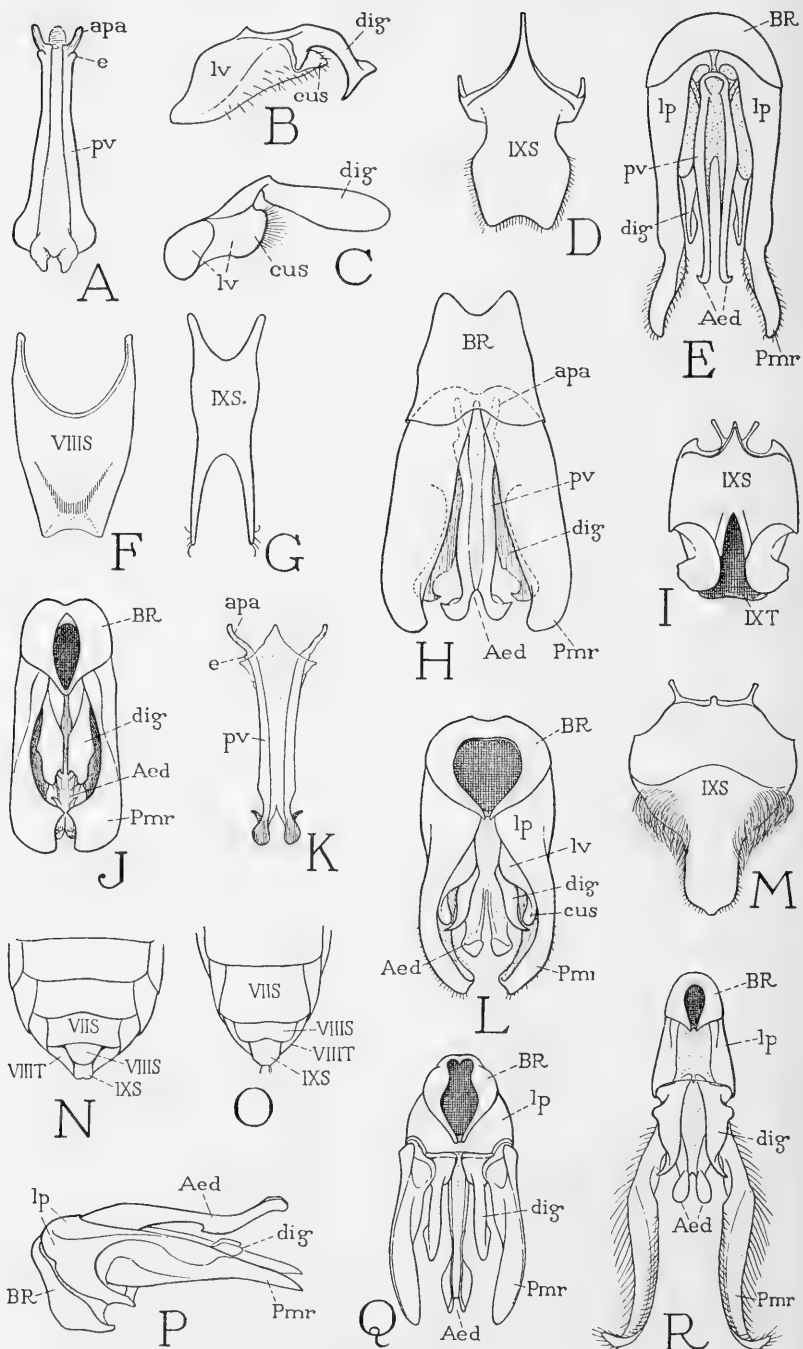
SPHECOIDEA

(For explanation, see page 79.)

SPHECOIDEA

(For explanation, see page 80.)
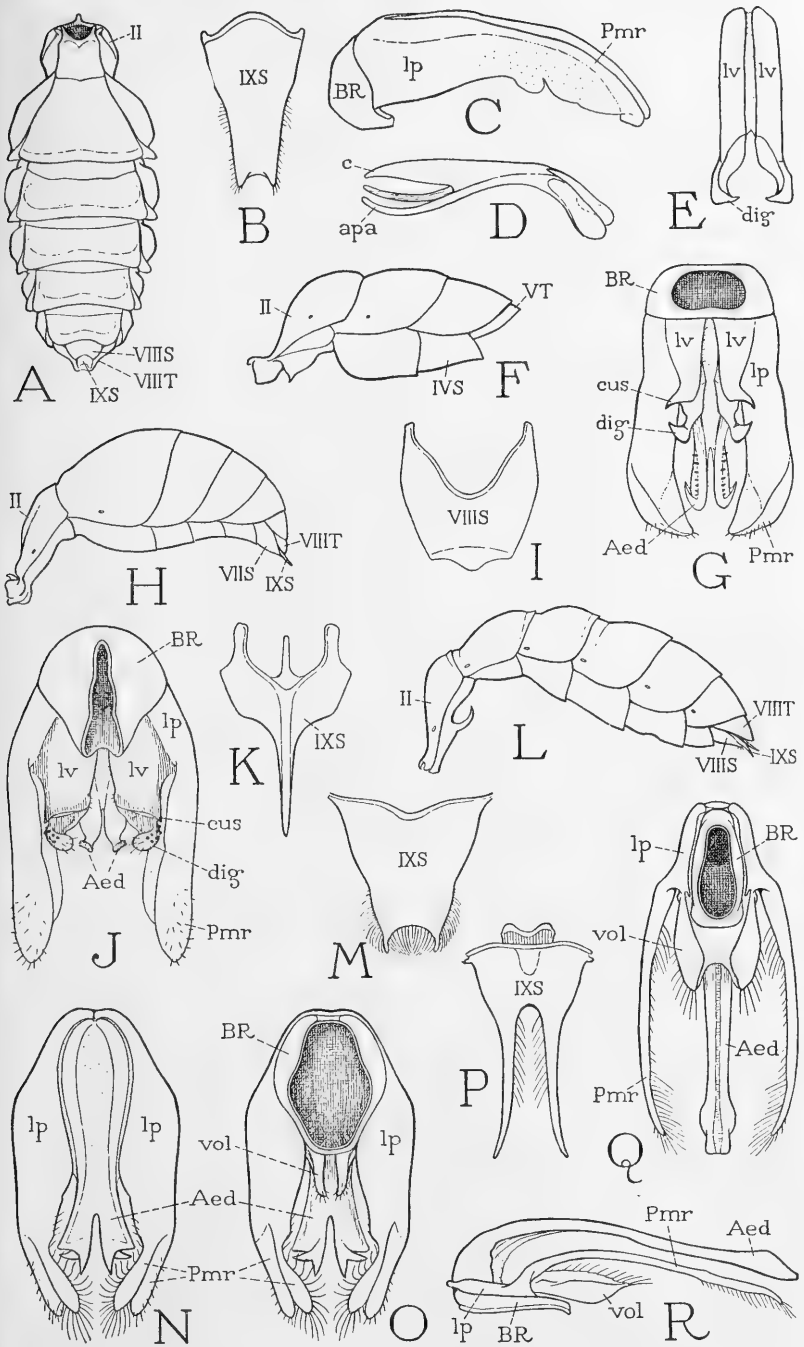
SPHECOIDEA

(For explanation, see page 80.)
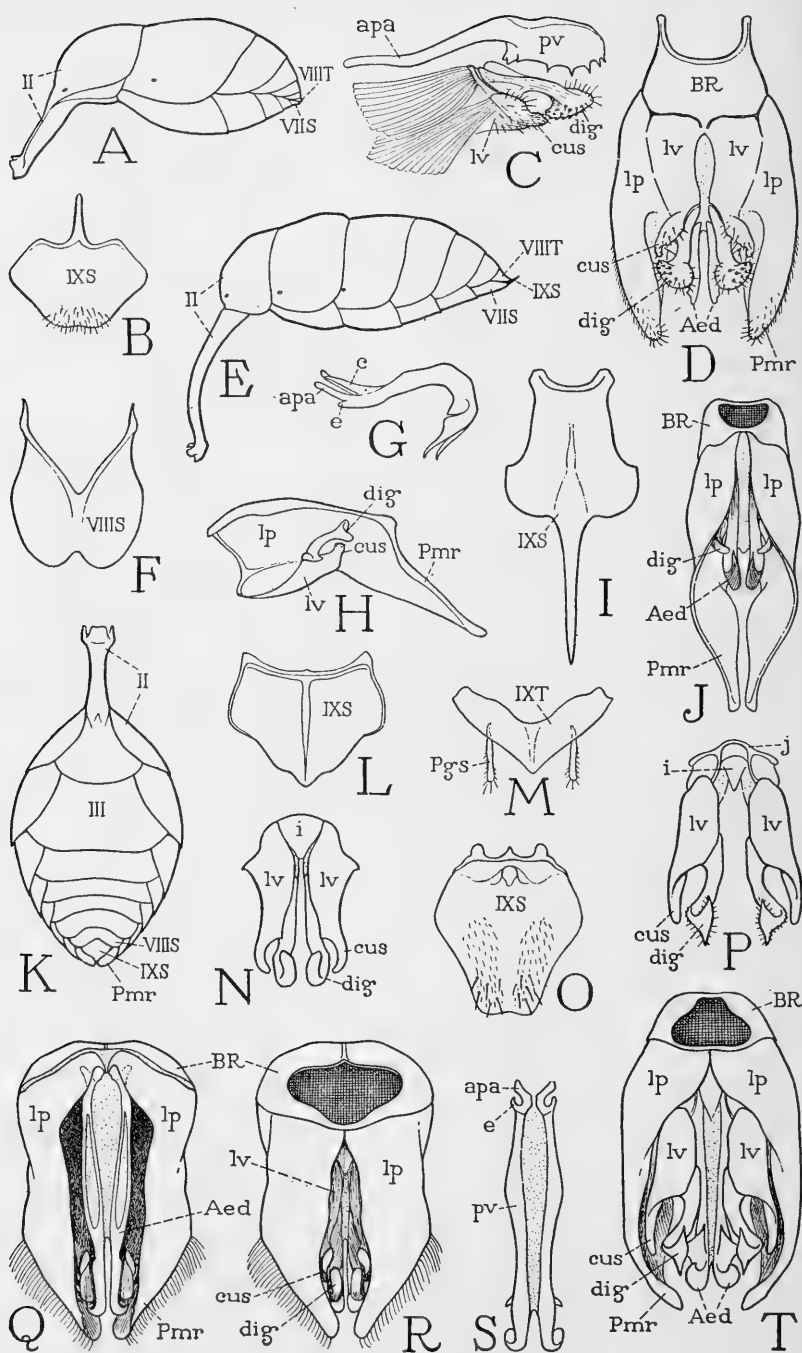
SPHECOIDEA

(For explanation, see page 81.)
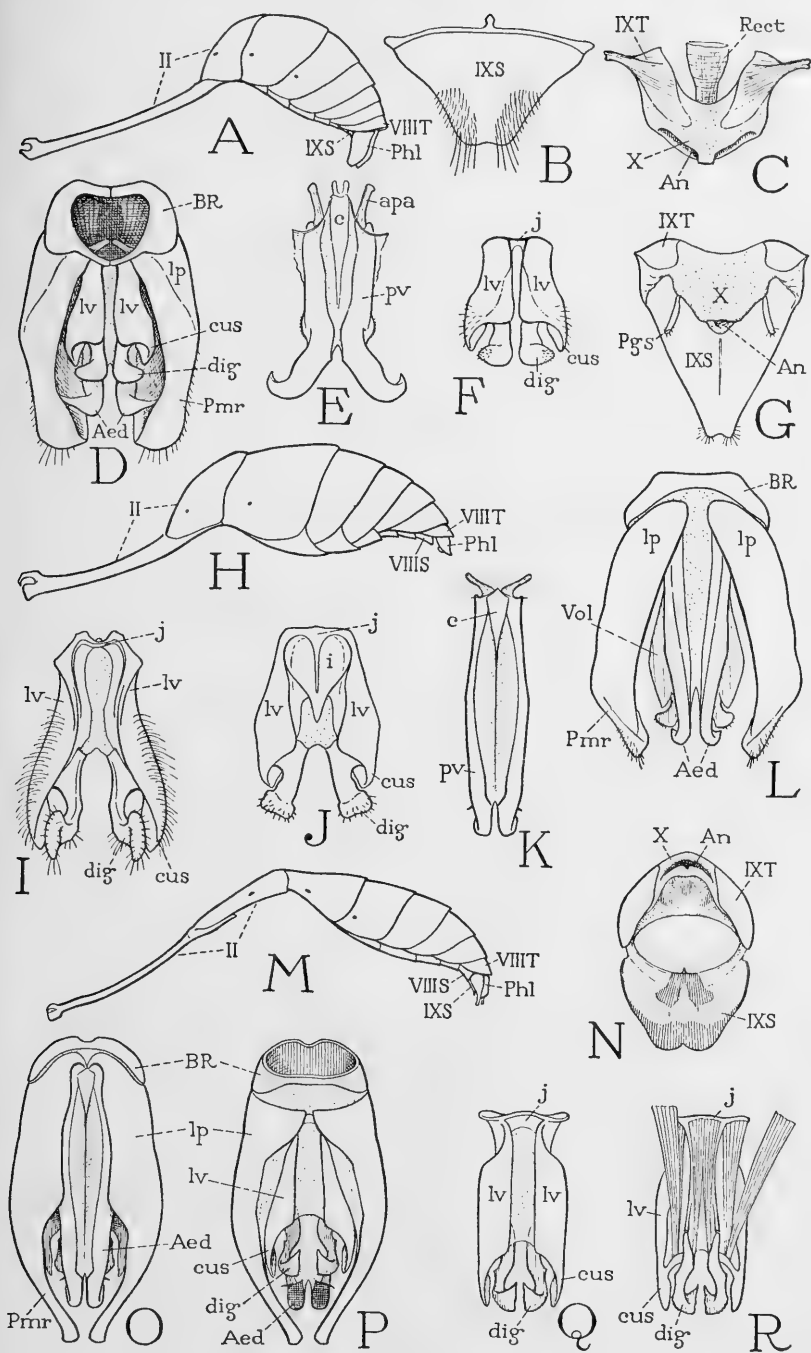
SPHECOIDEA

(For explanation, see page 81.)
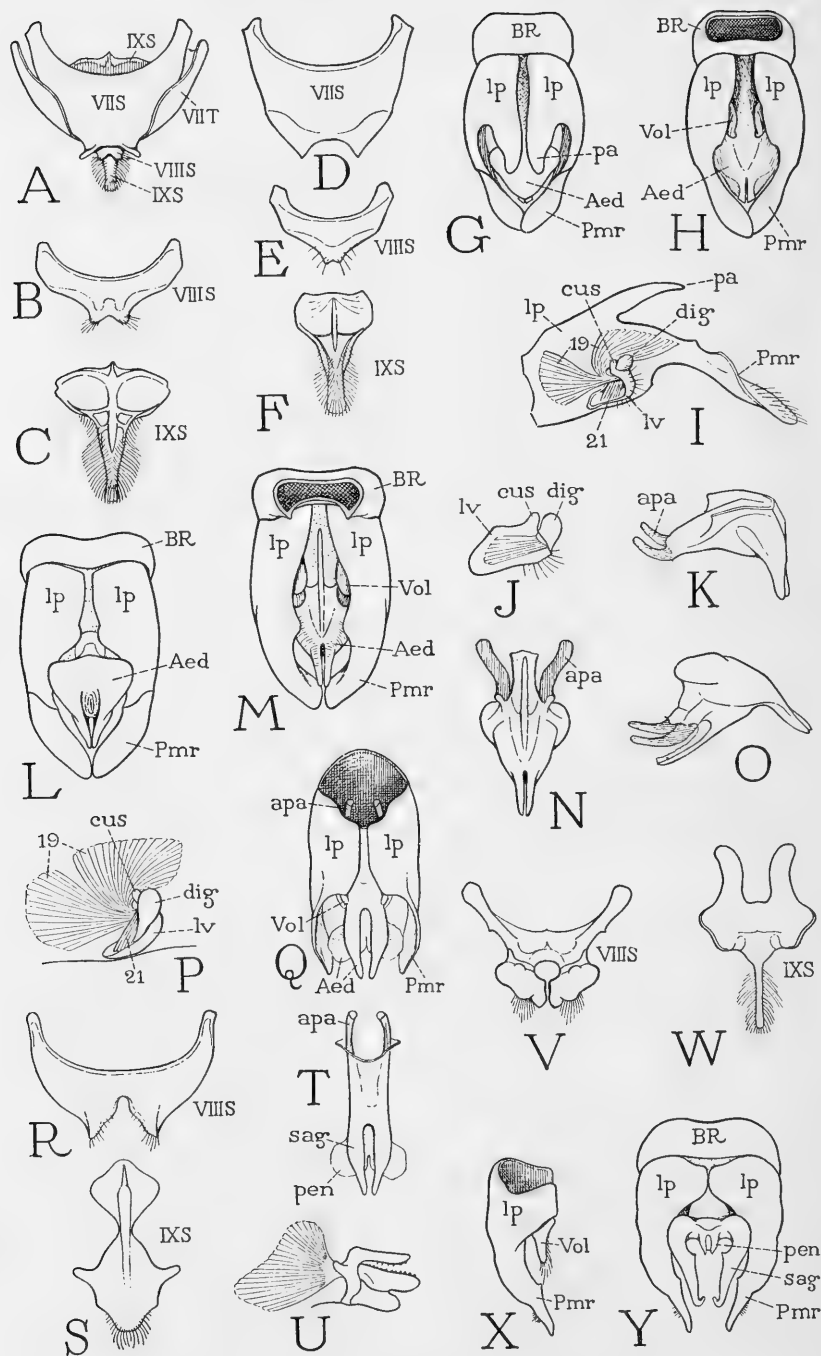
APOIDEA

(For explanation, see page 82.)
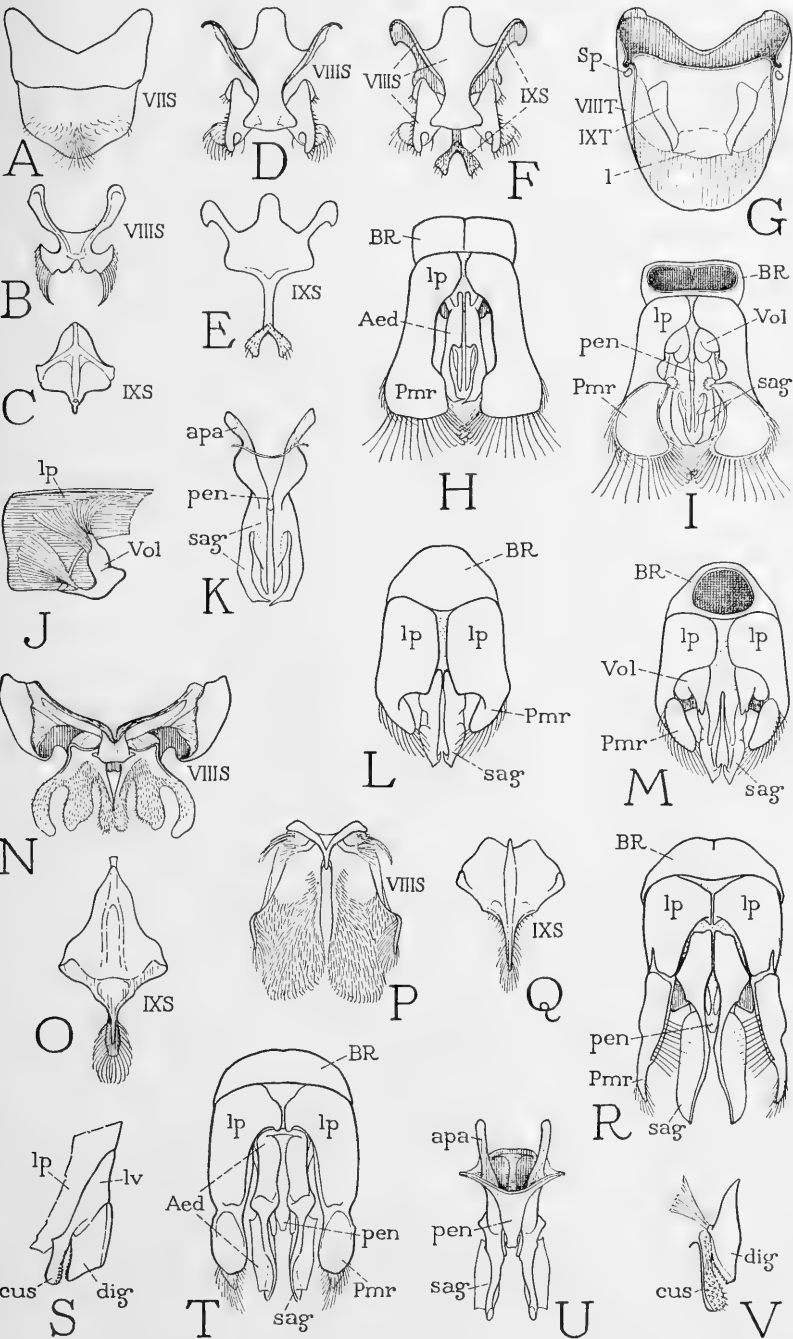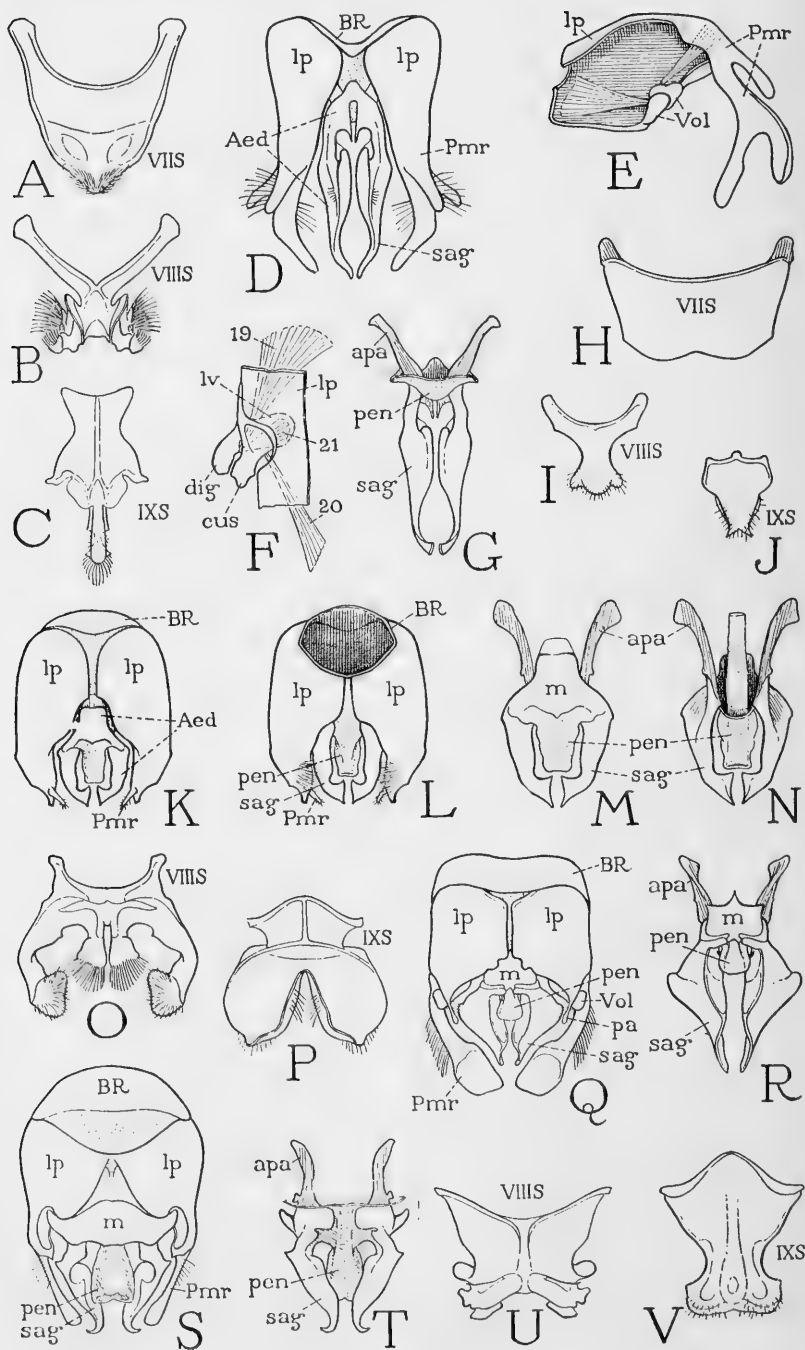
APOIDEA

(For explanation, see page 82.)

APOIDEA

(For explanation, see page 83.)
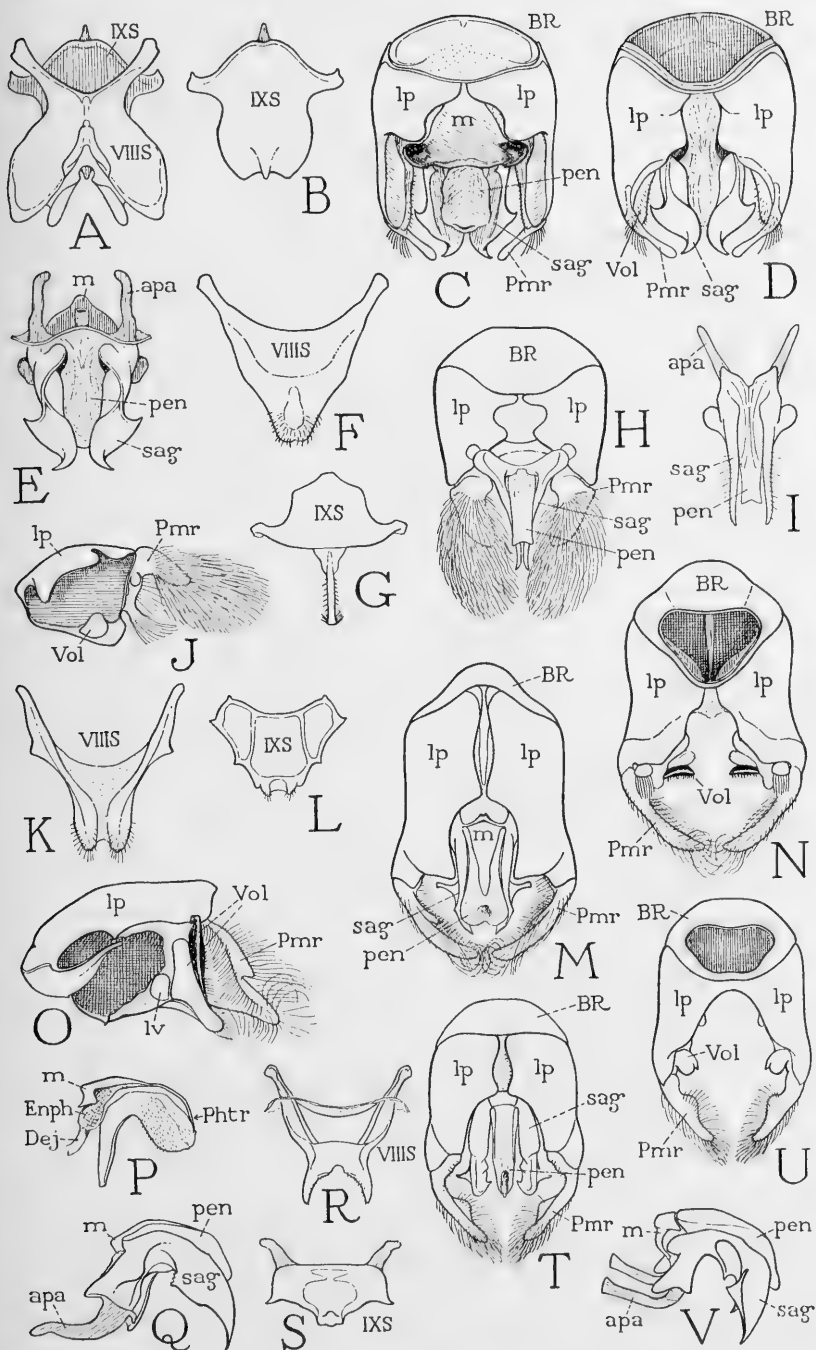
APOIDEA

(For explanation, see page 83.)
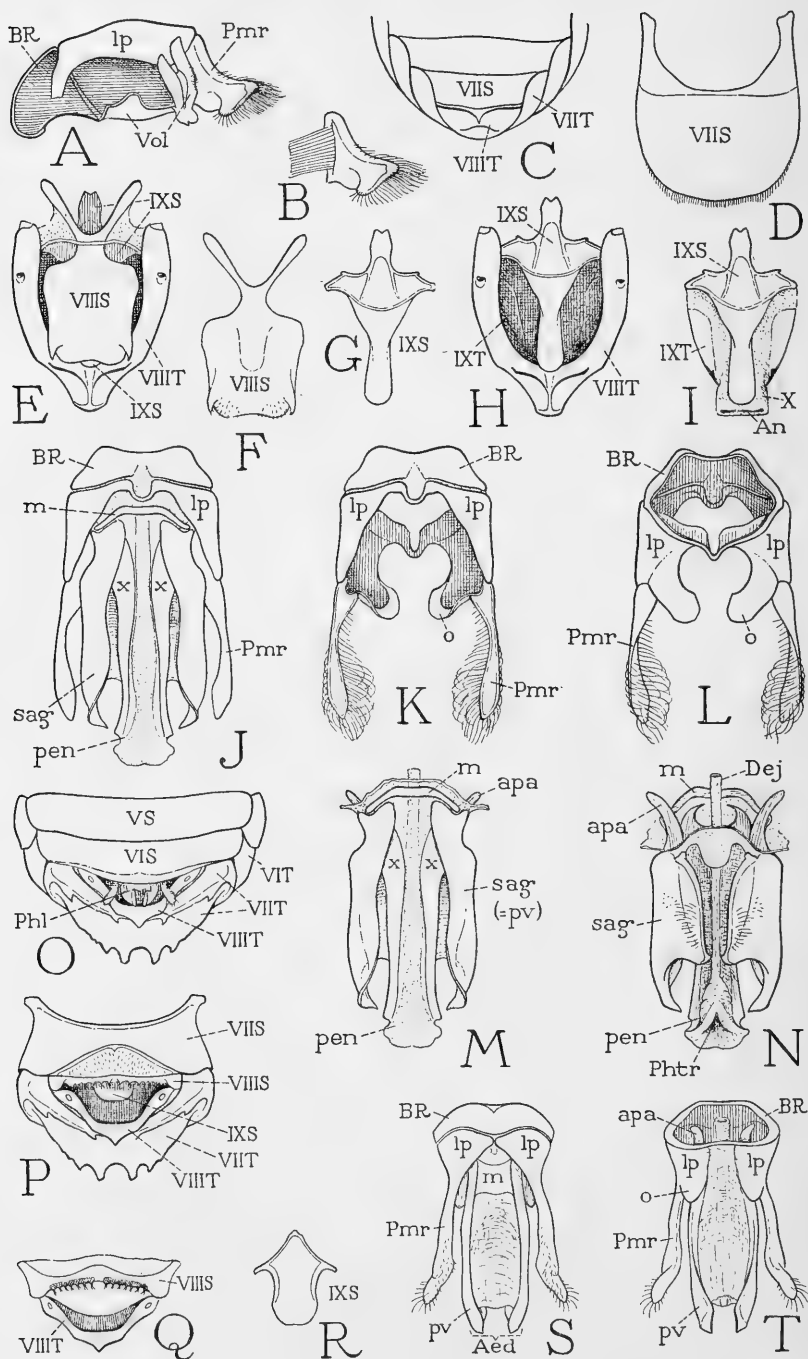
APOIDEA

(For explanation, see page 84.)
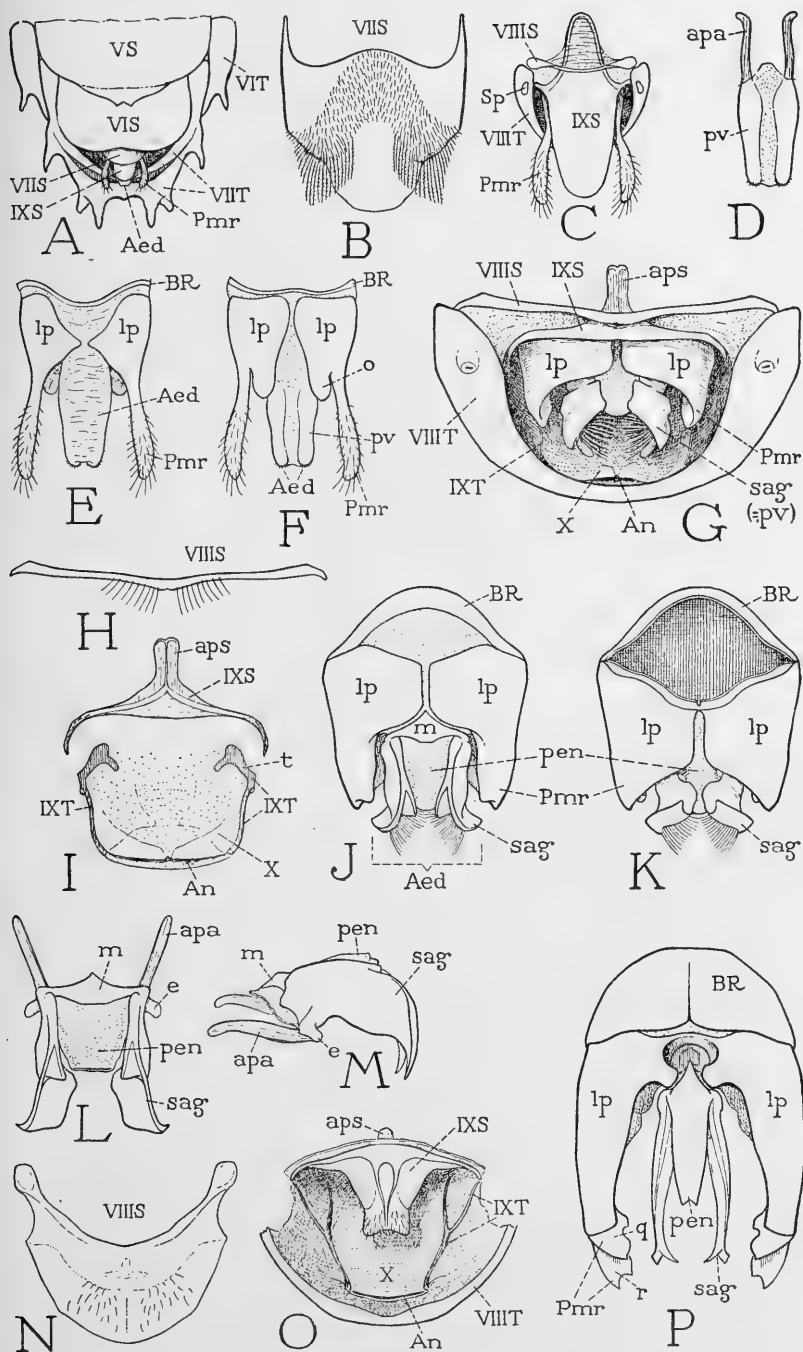
APOIDEA

(For explanation, see page 84.)
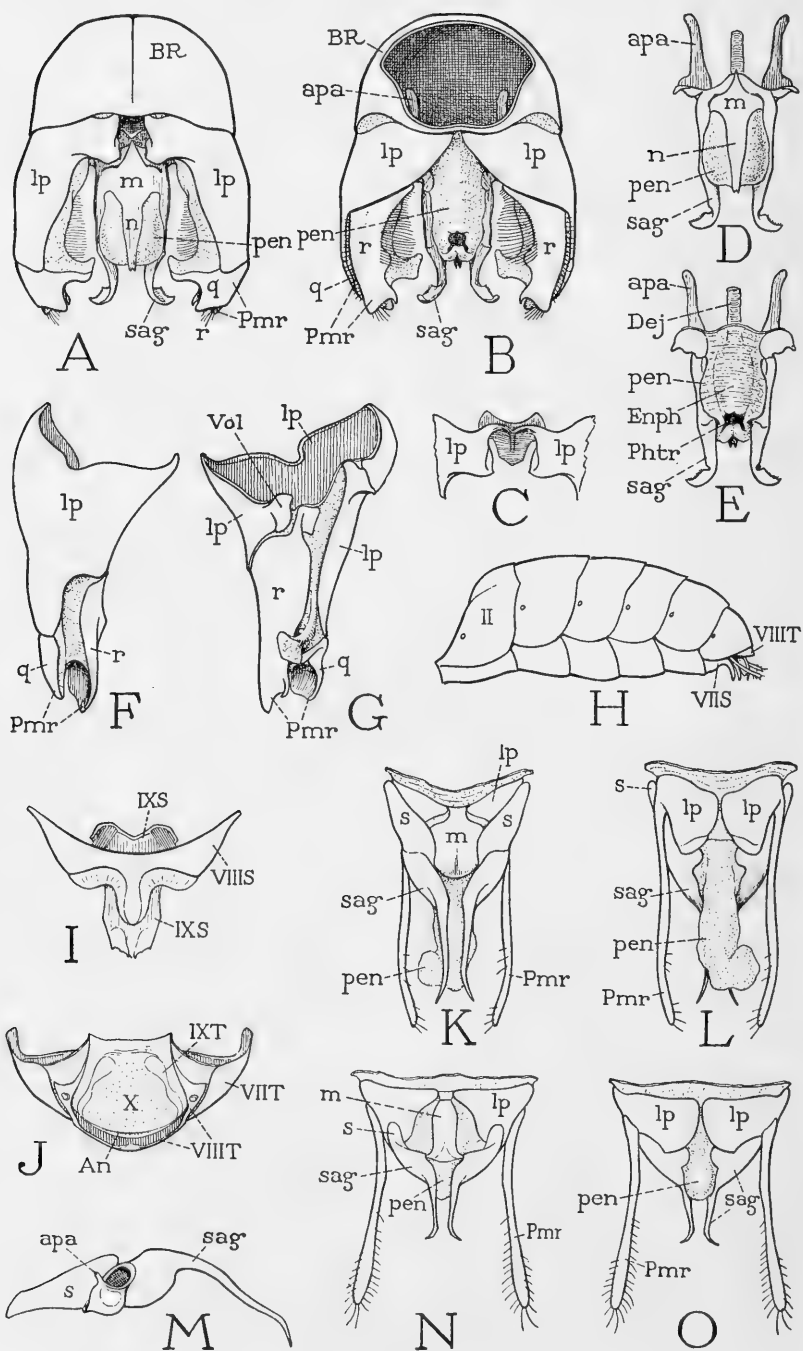
APOIDEA

(For explanation, see page 85.)
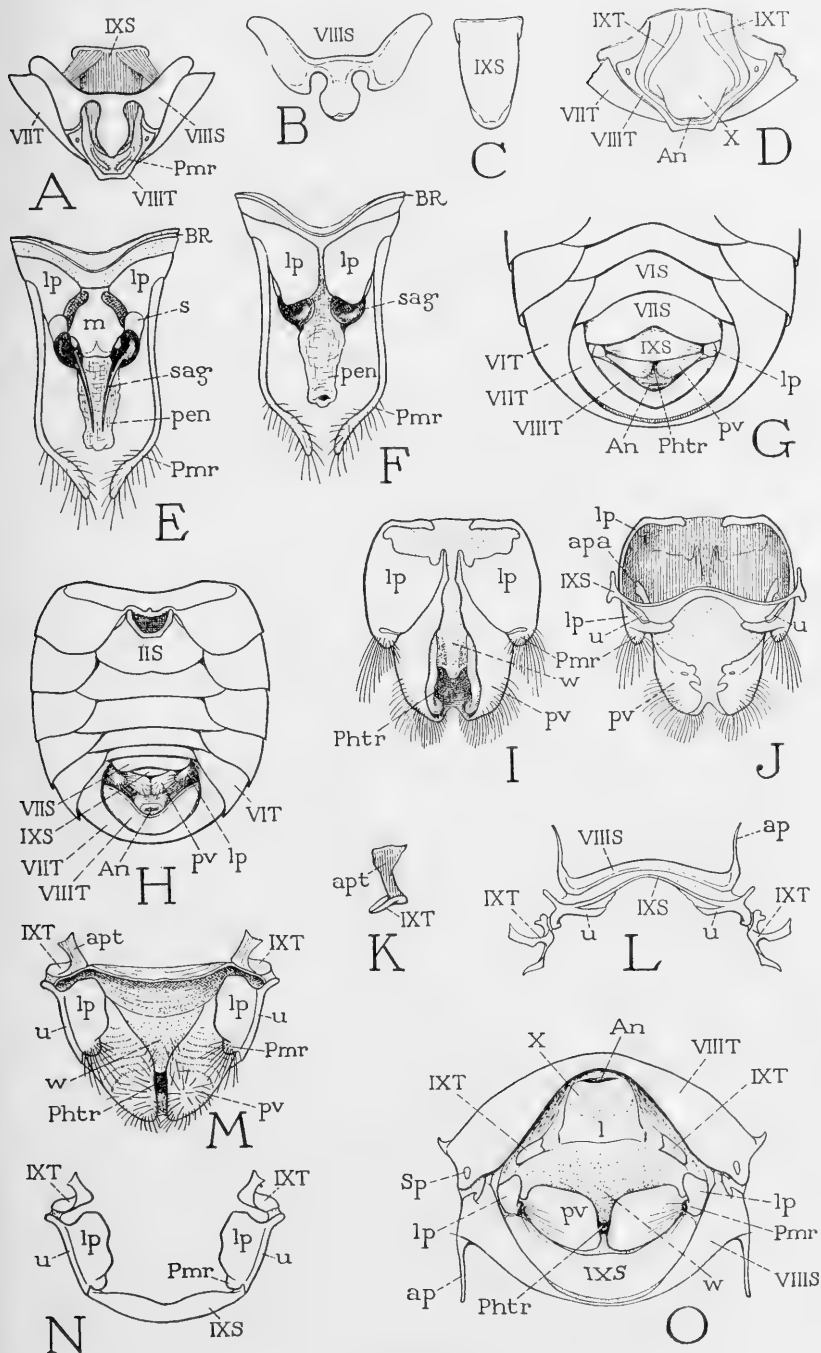
APOIDEA

(For explanation, see page 85.)
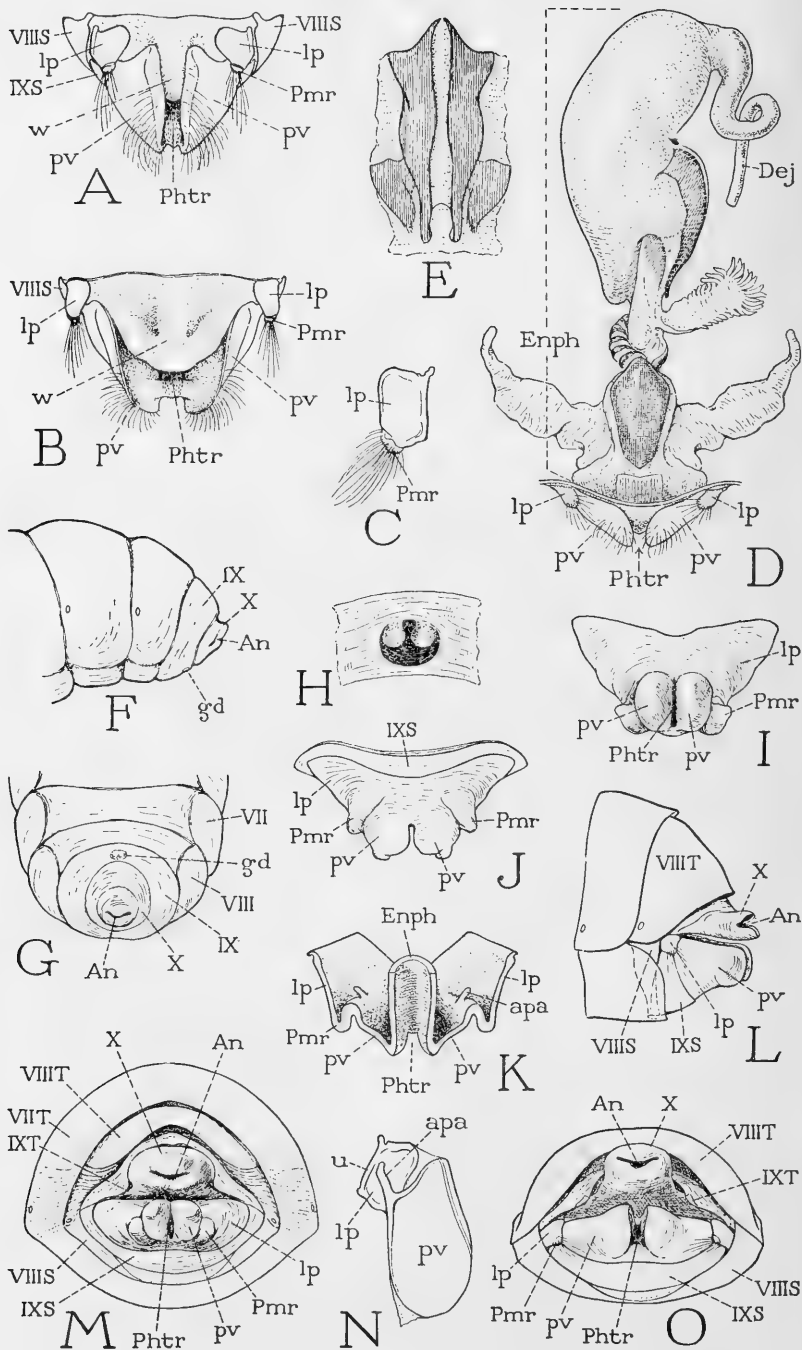
APOIDEA
(For explanation, see page 86.)

APOIDEA
(For explanation, see page 86.)

EVIDENCE OF EARLY INDIAN OCCUPANCY NEAR THE PEAKS OF OTTER, BEDFORD COUNTY, VIRGINIA

(WITH FIVE PLATES)

BY
DAVID I. BUSHNELL, JR.
Collaborator in Anthropology, Smithsonian Institution

(PUBLICATION 3601)

1. The site, partly graded, showing Flat Top in the distance.

2. The site in the foreground with the slope of Sharp Top beyond.

VIEWS OF THE MONS SITE BETWEEN THE PEAKS OF OTTER

EVIDENCE OF EARLY INDIAN OCCUPANCY NEAR THE PEAKS OF OTTER, BEDFORD COUNTY, VIRGINIA

(WITH FIVE PLATES)

BY

DAVID I. BUSHNELL, Jr.

Collaborator in Anthropology, Smithsonian Institution

(PUBLICATION 3601)

EVIDENCE OF EARLY INDIAN OCCUPANCY NEAR THE PEAKS OF OTTER, BEDFORD COUNTY, VIRGINIA

By DAVID I. BUSHNELL, Jr.

Collaborator in Anthropology, Smithsonian Institution

(With Five Plates)

Bedford County, in the southwestern part of Virginia, extends from the James River on the north to the Roanoke River on the south. The southeastern part of the county is comparatively level, but beyond, toward the north and west, it is crossed by the Blue Ridge with the Peaks of Otter rising near its northern boundary. It is a region of great natural beauty, with innumerable springs and streams. The mountain slopes are covered with forests of pine and hemlock, and many varieties of trees and plants are encountered throughout the area. Wild game was formerly plentiful in all parts of the county, but during the past few years the larger animals have become less numerous.

The Peaks of Otter, which rise in the extreme northern part of Bedford County, were, before the discovery of the country far westward, thought to be among the highest on the continent. This belief was suggested by Jefferson[1] when he wrote (p. 18) :

> The mountains of the Blue ridge, and of these the Peaks of Otter, are thought to be of a greater height, measured from their base, than any others in the country, and perhaps in North America. From data, which may sound a tolerable conjecture, we suppose the highest peak to be about 4000 feet perpendicular. . . . . The ridge of mountains next beyond the Blue ridge, called by us the North mountain, is of the greatest extent; for which reason they were named by the Indians the Endless mountains.

The two peaks are now known as Sharp Top and Flat Top. As stated by the United States Geological Survey, the elevation of the former is 3,875 feet, and of the latter 4,001 feet, which proves the accuracy of Jefferson's "conjecture."

There is sufficient evidence now available to suggest that man had occupied or frequented the region for generations, and it is thought that a careful examination of certain restricted areas near the Peaks of Otter will tend to substantiate the belief that the region surround-

---

[1] Jefferson, Thomas, Notes on the State of Virginia. Philadelphia, 1788.

ing the peaks had been occupied and reoccupied by native tribes for countless centuries—since the first nomadic bands entered the vast wilderness.

Ancient trails traversed the country. A trail coming from the west is known to have followed up the valley of the North Fork of Goose

Fig. 1.—A section of the Bedford sheet, reconnaissance map, United States Geological Survey. The location of the Mons site is indicated just north of the Peak, or Sharp Top.

Creek and to have continued through Powell Gap. Another trail may have led from Powell Gap to the valley of Little Stony Creek, between the two peaks.

A map of the region now being considered is shown in figure 1. This is a detail of the Bedford sheet, reconnaissance map, United States Geological Survey.

During protohistoric and early historic times Siouan and Iroquoian tribes are believed to have lived within the bounds of the present

Bedford County. Later, in 1670, the village of the Nahyssan, a Siouan tribe, was in or near the southern part of the county when it was visited by Lederer.[2] The exact location of the settlement will be difficult to determine. Lederer's text is vague and uncertain, and consequently not easy to follow, but according to his crudely drawn map the tribe was established on the right bank of a river, probably the Roanoke or Staunton. Swanton has traced the movements of the Nahyssan, Saponí, and Tutelo, when they may have traversed part of the county.[3]

In 1846 Schoolcraft recorded an old Cherokee tradition, told by a member of the tribe, that a Cherokee village had formerly stood near the Peaks of Otter. However that may be, it is evident that the region had attracted the native hunters from remote times and that it had been occupied by tribes of different stocks, possibly with centuries intervening between the periods of occupation. But it is not possible to state with accuracy the sequence of movements of tribes, and it is a fallacy to apply dates to any tribal migrations or settlements in the Mississippi Valley and eastward before the beginning of the historic era.

Swanton has suggested the possibility that the word Otter, as now applied to the two peaks and the streams, was derived from the Cherokee Atari or Ottari, translated mountain or high hill. The belief that this may be true is strengthened by the tradition that the Cherokee once occupied a village in the vicinity of the Peaks of Otter. Place names bestowed and used by the Cherokee may have persisted until after the coming of the first European settlers by whom the Indian name Ottari would, it is easily conceived, have been rendered Otter. All this, however, is purely hypothetical.

THE MONS SITE

Early in the spring of 1940 work in connection with the extension of the Skyline Drive, in the vicinity of the Peaks of Otter, exposed the site of an ancient Indian settlement. This was partly on the grounds of the recently demolished resort hotel, Hotel Mons, and for that reason the site will be designated the Mons site.[4]

---

[2] Lederer, John, The discoveries of . . . . Begun in March 1669 and ended in September 1670. London, 1672. Reprint 1902.

[3] Swanton, John R., Early history of the eastern Siouan tribes. *In* Essays in anthropology in honor of Alfred Louis Kroeber, Univ. California, 1936.

[4] I am indebted to the Rev. William Clarkson Marshall and R. L. Updike, of Bedford, for assistance and advice when we visited the site on July 10, 1940. The latter had written on April 21: "I have just returned from the site between

The site is a little west of north of Sharp Top, near several small branches that are the sources of Sheep Creek and Little Stony Creek. It is mostly surrounded by higher ground, and consequently a village or camp standing here in the midst of the dense primeval forest would have been secluded and well protected. Two views of the site, or rather part of it, are shown in plate 1.[5] Both were made from the same point, on the north side of the course of the Skyline Drive, which is to be seen, partly graded, in the foreground. Rev. William C. Marshall, Dr. Frank H. H. Roberts, Jr., and the writer visited the site on October 15 in an endeavor to determine the extent of the occupied area, but this proved to be impossible as the surface remained thickly covered with grass and brush. However, it could be traced far beyond both sides of the new roadway and is evidently rather extensive, being crossed by two small branches and having several springs issuing from beneath the higher ground by which much of the site is bordered.

Many types of stone artifacts were exposed during the removal of the top soil. Some pieces appear to be, and probably are, much older than others, but as all came from the surface or not more than a few inches below the sod line, it is not possible to determine the relative position or sequence of the various forms. The land had formerly been cultivated, which would have caused any material that may have accumulated in heaps in or about that part of the occupied area to become scattered and intermixed.

The artifacts recovered from that part of the site through which the new roadway passes, and from the adjacent land, include flake-knives and scrapers, projectile points and other small flaked objects; larger scrapers and several forms of edged implements; axlike implements, some with and others without a groove; pebbles used as hammers and others which may have served as pestles. Fragments of steatite vessels and small bits of earthenware were encountered in the disturbed soil. Two Folsom points have been found on the site mingled with the other material.

---

the Peaks of Otter . . . . The construction gang on the Skyline Drive are now working in this little valley, and the sod and grass has been stripped for the width of the drive for the entire length of the valley. During the past week there has been much rain, and every uncovered point and chip of stone stands out, easily identified." Many of the specimens described and illustrated on the following pages were collected by Updike on April 21, 1940, and others were found during different visits to the site.

[5] The photographs were made by R. L. Updike, June 27, 1940.

Quantities of flakes of many varieties of stone are found throughout the area, also many fractured pebbles, indicating that work had been done at the site. The stones [6] include argillite, metamorphosed rhyolite, feldspar porphyry, felsite, quartz, quartzites, chalcedony, jaspers, and cherts. Several rounded pieces of sandstone that had served as hammerstones were found, but no fragments of the stone were discovered.

Pebbles and boulders exposed in the stream beds, and on hillsides, obviously supplied the stone used in fashioning the great majority of objects now found scattered over the site. Soapstone, argillite, and sandstone had been brought in, though not necessarily from a great distance.

Examples of the stone artifacts and fragments of earthenware vessels found on the Mons site are illustrated and may be briefly described:

Plate 2.—The occurrence of a large number of flakeknives and small scrapers is the more interesting and important inasmuch as similar objects are seldom found in Virginia. The flakeknives range in size from those less than an inch in length to others somewhat longer than the four specimens shown in the top row. All are thin flakes struck from a mass and do not reveal any secondary chipping. The one on the left, top row, is made of yellow or brownish mottled jasper; the next two, dark chert; and the larger specimen on the right, moss-agate. Others found with these were made of quartz and quartzite. The sketch of *a,* in figure 2, shows the curvature of the flake and the bulb of percussion at the bottom. The edges of all are slightly roughened or serrated, the result of use.

A few specimens, represented by *b* and *c,* suggest a composite knife and scraper, having two edges well defined and both showing the effect of use. Other specimens, obviously scrapers and not knives, are short and broad at the worked edge. Examples of this type are shown in *d, e,* and *f.*

All were probably employed for various purposes, although certain forms were undoubtedly better suited for some particular use than were others.

Plate 3.—Various types of projectile points, and small flaked objects of unknown use found on the site are illustrated in this plate.

Specimens *a.* All are made of white quartz, so plentiful in parts of Virginia, and which was used extensively in making projectile

---

[6] Identified by W. F. Foshag and E. P. Henderson, Department of Geology, U. S. National Museum.

points and other small implements. The forms recovered from the Mons site are similar to others found on widely separated areas in piedmont and tidewater Virginia. As the surface of quartz is not altered by exposure to the natural elements through the centuries, it is not possible to judge the comparative age of the specimens by their appearance. Some pieces may be centuries older than others, though all appear the same.

Specimens *b*. Small points made of jasper, chert, quartz, and other stone. Part of a perforator is shown at the left in the upper row. Several specimens in this row are made of a banded flint that resembles the stone obtained at Flint Ridge, Licking County, Ohio, and it is
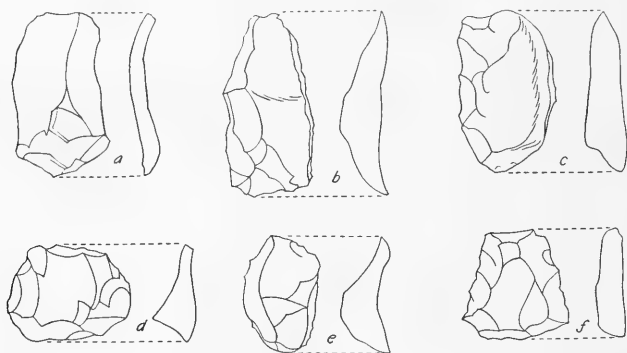

Fig. 2.—Sketches of six specimens of flakeknives and scrapers illustrated in plate 2, showing the thickness and curvature of the flakes. ½ natural size.

believed to have been derived from that source. The three pieces at the right in the lower row, all made of chert, are of a type seldom found in Virginia. Concerning these particular specimens Updike stated in a note addressed to me:

Many points from this site have broad bases and deep notches, by these characteristics differing from those found on other sites in Bedford County. So far as I know, these are not found in any other location in this county.

These specimens, with deep side notches, are similar to many found in McLean County, Kentucky, recently described and illustrated. They are of a distinctive and specialized type. The sites where the points were encountered were assigned, by the discoverers,[7] "to the oldest horizon in Kentucky." These were evidently the "Round Grave people" of other narratives. Although it will be conceded that these

---

[7] Webb, Wm. S., and Hagg, Wm. G., Cypress Creek villages, sites 11 and 12, McLean County, Kentucky. Univ. Kentucky, Reports in Anthrop., vol. 4, No. 2, fig. 20, March 1940.
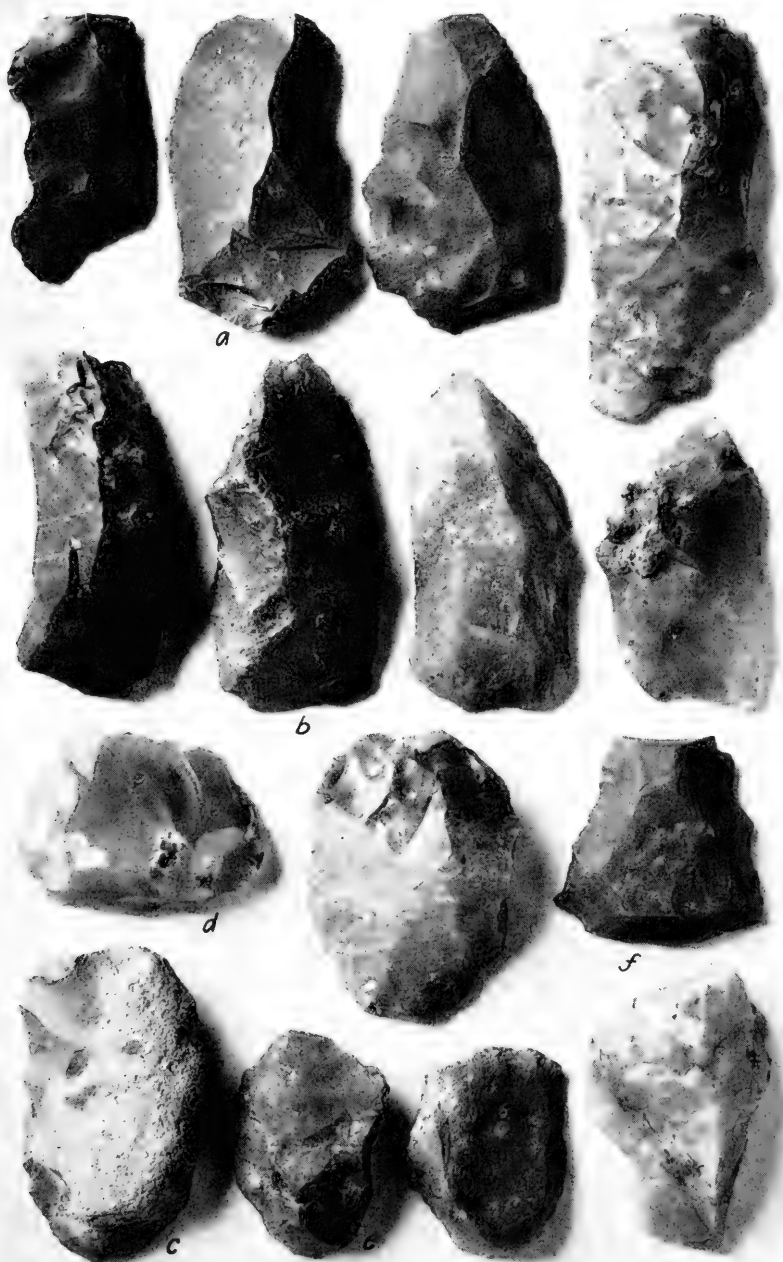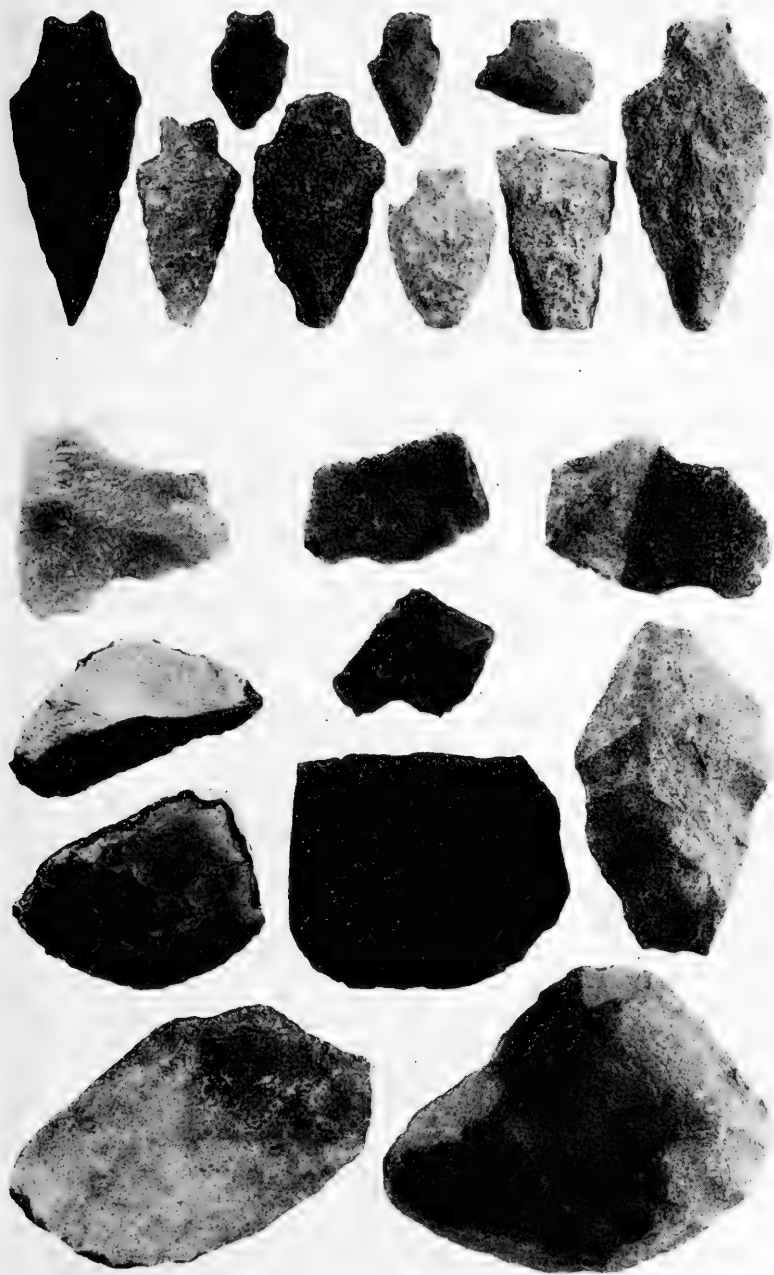
SPECIMENS FROM THE MONS SITE. FLAKEKNIVES AND SCRAPERS
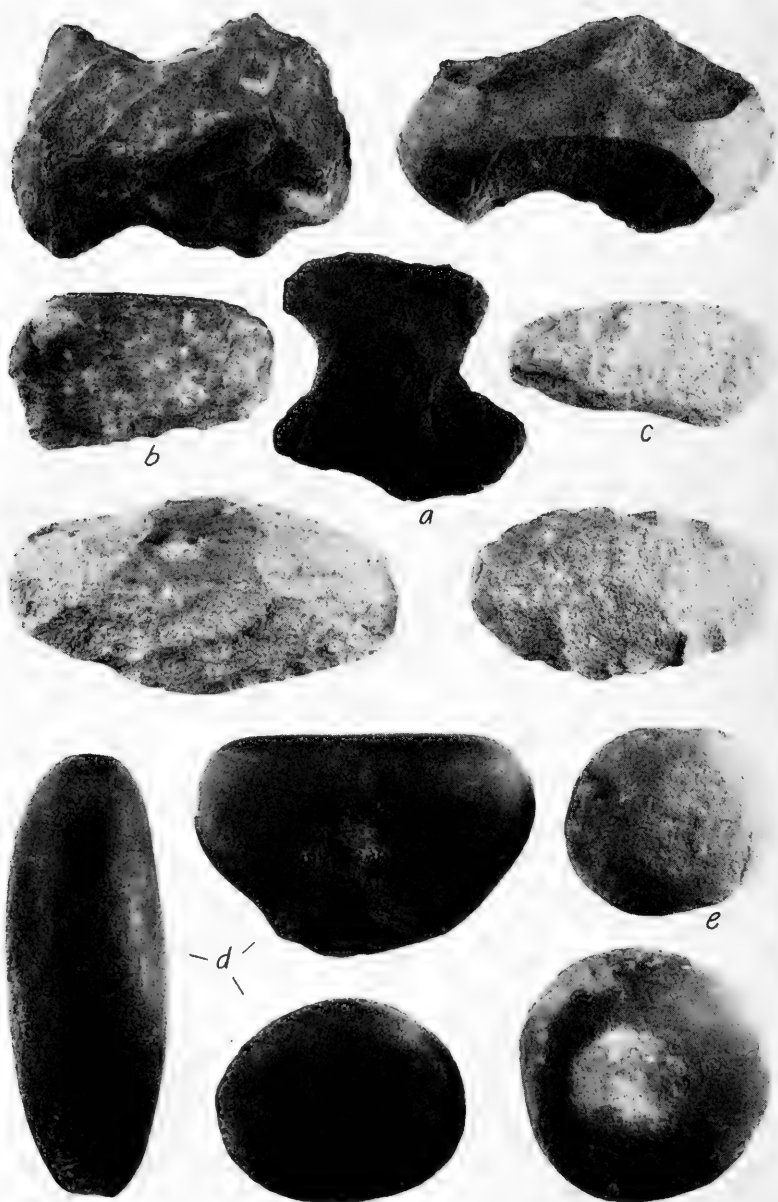
Natural size. U.S.N.M. No. 382135.
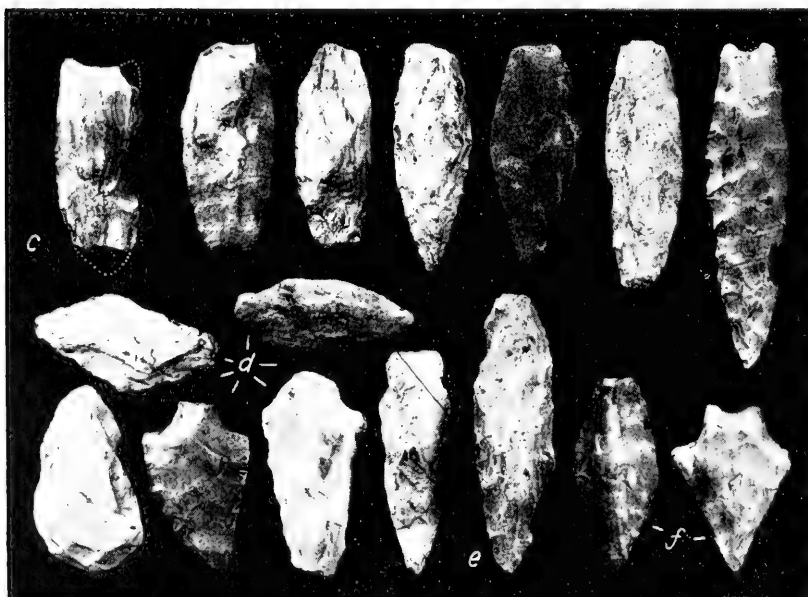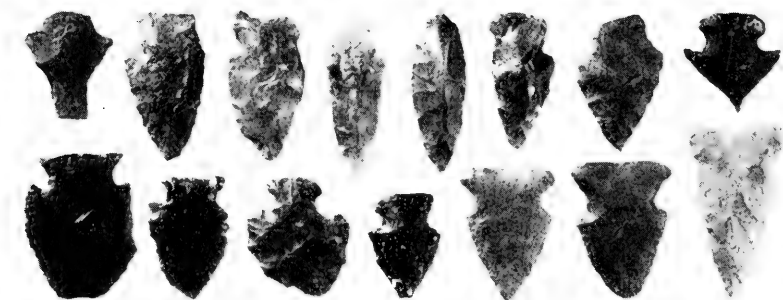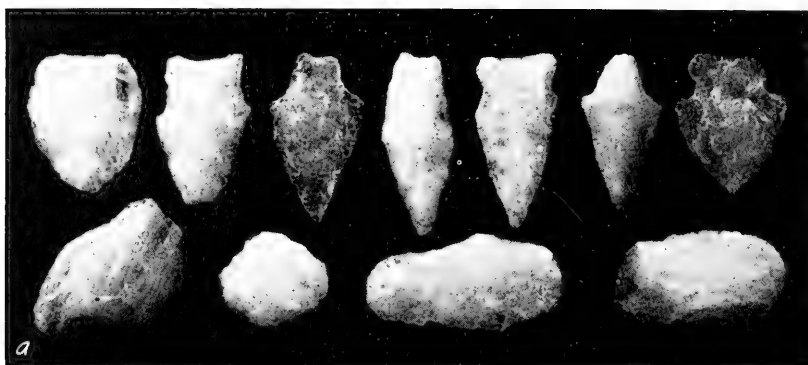
SPECIMENS FROM THE MONS SITE. PROJECTILE POINTS AND OTHER
SMALL FLAKED OBJECTS

½ natural size. a, U.S.N.M. No. 382136; b, U.S.N.M. No. 382137;
c, U.S.N.M. No. 382138.

SPECIMENS FROM THE MONS SITE. UPPER, PROJECTILE POINTS OR
BLADES. LOWER, SCRAPERS AND EDGED IMPLEMENTS

½ natural size. Upper, U.S.N.M. No. 382139; lower, U.S.N.M. No. 382140.

SPECIMENS FROM THE MONS SITE. ABOVE, SEVEN FLAKED IMPLEMENTS.
BELOW, FIVE PEBBLES SHOWING THE EFFECT OF USE

⅓ natural size.

specimens are very old, it is believed that even earlier material has been found in Kentucky.

The seven pieces forming the row beginning with *c* are made of schists.

Specimen *c*. This is a Folsom point made of quartz schist. The stone is a very dark gray, approaching black, as revealed by a small fracture, but the surface is now altered to a light gray color through long exposure to the natural elements. The three specimens to the right of *c* are similarly altered. Next beyond are two pieces that have become so greatly weathered that their surfaces are smoothed and evidence of flaking is scarcely discernible. The long specimen on the right is less deeply altered than the preceding, though the surface of the dark gray stone has now changed to a very light greenish gray.

Specimens *d*. Six specimens made of argillite. The surfaces of all are altered, some to a greater degree than others. The piece on the lower left, a side scraper, is similar to specimens discovered on the site of the ancient Algonquin village of Pissaseck, in Westmoreland County, on the left bank of the Rappahannock River.[8] It also resembles specimens belonging to the so-called argillite culture, discovered on sites in the Delaware valley. The source of the argillite has not been discovered, but it may have been not far from the site.

Although a few scattered projectile points and other small objects made of argillite have been found frequently on village sites in Virginia, I have never before encountered them in such large numbers, nor have they been found to constitute so large a proportion of all the material gathered from a site as here. Quantities of flakes and small broken pieces of the stone are scattered over the site, thus proving that the stone had been fashioned into projectile points, scrapers, or knives near where such pieces were discovered.

Specimen *e*. A crudely flaked object of felsite. The surface is weathered to a light brownish color.

Specimens *f*. Two pieces made of a very dark or black quartzite. It is very fine grained, and the surfaces of both are now altered to a light brownish gray, with darker bands.

Obviously the 16 specimens just mentioned are very old, and some of them may have belonged to the earliest occupants of the valley.

Plate 4.—Nine examples of points made of a variety of stones are illustrated in the upper part of the plate. The surfaces of all are greatly weathered. At the left is a well-flaked specimen made of

---

[8] Bushnell, David I., Jr., Indian sites below the Falls of the Rappahannock, Virginia. Smithsonian Misc. Coll., vol. 96, No. 4, pl. 3, p. 19, 1937.

dark diabase; however, the surface is now rough and decomposed and is altered to a greenish color. Very few objects made of diabase appear to have been found on the site.

In the lower part of the plate are shown several forms of scrapers and edged implements made of chert and quartzite. At the top are four scrapers with concave cutting edges. Three are made of quartzite, and one, the smallest, is made of chert. A similar piece made of white quartz is illustrated in plate 3, a. The large specimen in the center is not more than 5/16 inch thick. It is made of a thin piece of dark grayish quartzite, and the lower edge had been sharpened by the removal of flakes from both sides. This may have been used as a knife with the upper part inserted in a handle made of wood or antler.

The two larger specimens at the bottom of the plate are spalls struck from quartzite pebbles or boulders. The natural surfaces are shown in the photographs, but they are weathered on all sides. The edges of both pieces are worn and battered from use. Both are thick and would have been used as hand tools, not hafted.

Plate 5.—Examples of the larger implements, many of which have been found on the site, are illustrated.

Above are seven flaked objects, all of which had probably been hafted and used as weapons or tools. All are made of quartzite of different texture and color.

Specimen *a,* with unusually deep notches, is made of a black, fine-grained quartzite like that of the three pebbles, *d,* and the implement may have been fashioned from a similar pebble. The sharp edge of *a,* part of which is missing, is shown at the bottom in the photograph. It is an interesting, crudely made piece.

The two smaller specimens, *b, c,* are made of a light-colored quartzite, and the surfaces of both are deeply weathered; however, the surfaces of the larger specimens above have not changed since the flakes were removed. This condition may indicate a great difference in the age of the specimens.

Below are five natural pebbles, all of which had been used. The three black quartzite pebbles, *d,* have battered edges, evidently caused by use. They would have been useful for many purposes in and about the camp. The long specimen on the left may have been used as a pestle. The small specimen, *e,* is made of a reddish sandstone and is slightly pitted on opposite sides. The larger hammerstone below *e* is a natural quartzite pebble, gray in color though the exposed surface is somewhat darker, as shown in the photograph. The edge is battered, and the stone is roughly pitted on opposite sides.

The specimens illustrated in this plate do not present any unusual features. Obviously they belonged to more than one period of occupancy.

FOLSOM POINTS

Small points or blades of the type now known as Folsom points have been found in Virginia and elsewhere in the eastern United States. They constitute a very distinctive group, and although they closely resemble the Folsom points occurring in the northern part of Colorado as discovered by Roberts,[9] and found in other localities both north and south, they are not identical in all details. Many of the eastern points are longer in proportion to their width than are the western specimens, and often lack the long channel flakes, passing from the concave base and extending down both sides, which constitute one of the characteristic features of the western points; however, some of the pieces found in the East possess this feature. Nevertheless, one detail is common to all specimens from both East and West—the smoothing of the edge of the concave base and of the edges for a distance of an inch or more beyond the base. For what reason or by what means this was accomplished is not known, but it is always apparent and must have been done intentionally.

Beautiful examples of eastern Folsom points have been found in and near Bedford County; however, with the exception of two specimens all have been found separate from other material, on a hillside or in a field where no traces of a camp or village were discovered. The same condition is believed to apply to the occurrence of all similar specimens wherever encountered, in Virginia or elsewhere. Examples of Folsom points may have been found previously on village sites or associated with burials in the East, but if so we have been unable to learn of such discoveries.

The two examples of Folsom points known definitely to have been found on the site of an ancient settlement, in contact with other artifacts, were discovered on the Mons site. One specimen, a fragment of a point, is shown full size in figure 3. The entire finished edge of the fragment is smoothed, a characteristic feature, and the whole surface is smooth and glossy. Obviously the point was broken after it had been finished and possibly used. It is made of a rather light gray chert. Many small flakes of the same stone are scattered through the soil on the site.

---

[9] Roberts, Frank H. H., Jr., A Folsom complex: Preliminary report on investigations at the Lindenmeier site in Northern Colorado. Smithsonian Misc. Coll., vol. 94, No. 4, June 20, 1935.

The second example of a Folsom point from the Mons site is illustrated half size in plate 3, *c*. I found this specimen during a visit to the site on September 5, 1940, at the edge of the surface cut away in grading the Skyline Drive, on the north side and less than 50 yards from where the fragment shown in figure 3 was discovered several years ago.[10] It is made of a very dark quartz schist with the surface now weathered to a light gray. It has been fractured in two places, as indicated by the dotted lines added on the photograph.
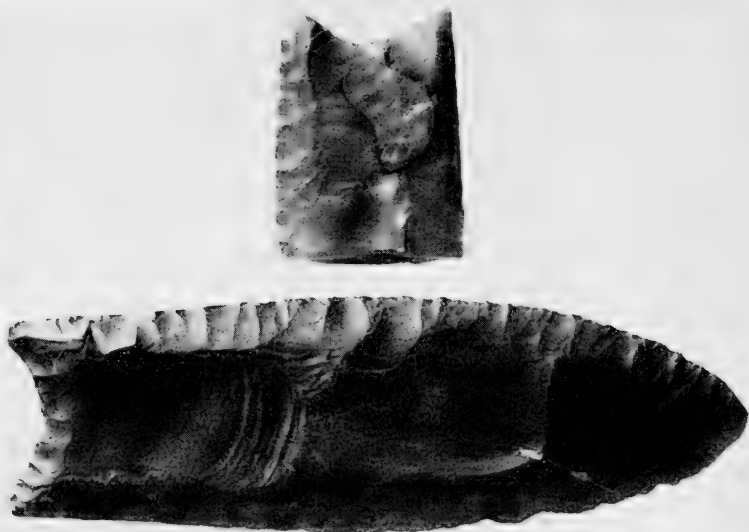

Fig. 3.—Folsom points. Above, fragment made of gray chert, found on the Mons site. Below, specimen made of red jasper, found in the valley about 2 miles south of the Mons site. Natural size.

The fractured surfaces are altered to the same degree as is the balance of the exposed surface of the stone. Although the entire specimen is worn from exposure, it is still possible to detect the smoothed edge of the concave base and the smoothed edges extending down the sides from the base, one of the curious features of all points of this type. The specimen is crude when compared with many other examples found in Virginia, but the stone of which it was made was difficult to work and a channel flake could not have been removed, as would have been possible had it been made of chalcedony or jasper. Though

---

[10] This was found by R. L. Updike, with whom I again visited the site on September 5, 1940.

less finished than many pieces, it is interesting as coming from a site that had been occupied from remote times.

An excellent example of a Folsom point was found a few years ago on a rocky hillside, in the valley of Little Stony Creek, about 2 miles southeast of the Mons site. The specimen is shown full size in figure 3. It is made of a dark red jasper, now worn smooth. A long channel flake had been removed from the side shown in the photograph, a feature more clearly defined in this than in most specimens from Virginia. A shorter flake had been taken from the other side. Small flakes of red jasper, similar to the stone of which the point was made, have been found on the site.

Other points of equal interest have been found in Bedford County, though at a greater distance from the Mons site.

SOAPSTONE VESSELS

Several pieces of soapstone or steatite vessels have been found on the site. One fragment is a handle that had extended from near the rim of a vessel. The vessel appears to have been rather large, and it had become smoothed and worn from long use. The surfaces of the pieces of stone are pitted and disintegrated, and all are of a light gray color. The stone was probably obtained at the quarry in the southeastern part of Bedford County, between Little Otter and Big Otter Rivers. Many broken, unfinished vessels have been collected from the surface of the quarry workshop,[11] but the quarry has not been carefully examined.

Many ancient soapstone quarries occur in Virginia. The first to be discovered and recognized as having been worked by Indians was at Chula, Amelia County. It was described in the Smithsonian Report for 1878, and soon others became known. The period to which the quarries should be attributed has not been determined. There are no accounts of Europeans' witnessing the use of soapstone utensils by the Indians of Virginia, and relatively few fragments of such pieces are encountered on the sites of native villages. However, the vast number of vessels broken and abandoned at the quarries proves that many had been made and used.

POTTERY

Fragments of pottery are found scattered through the soil, but all are very small and greatly decomposed. Five specimens are shown natural size in figure 4.

---

[11] Bushnell, David I., Jr., The use of soapstone by the Indians of the Eastern United States. *In* Ann. Rep. Smithsonian Inst. for 1939, p. 471, 1940.

Specimens *a.* I believe the impressions on the outside are of coiled basketry and that these specimens are of the earliest type of earthenware encountered in the Middle Atlantic region. A few pieces of similar ware have been found on widely separated sites. Examples were discovered by Harrington [12] in the upper valley of the Tennessee associated with material that belonged to the Round Grave people, the earliest of three distinct cultures encountered in that area, the last and most recent of which were the historic Cherokee. The
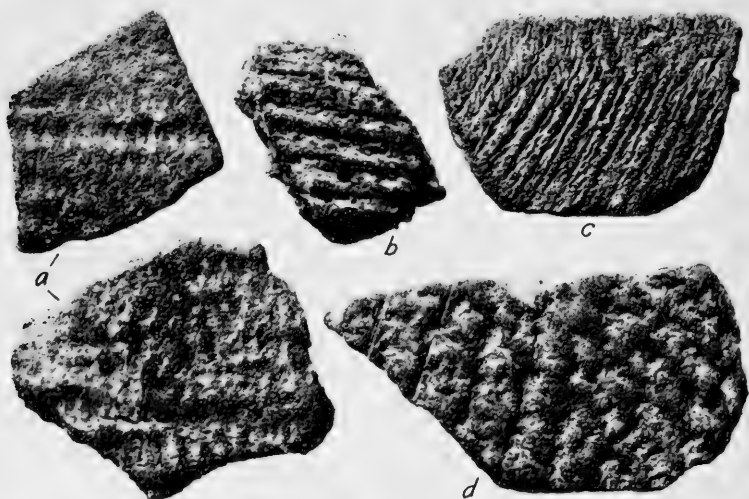

Fig. 4.—Fragments of pottery from the Mons site.
Natural size. U.S.N.M. No. 382141.

two sherds, *a,* are very hard, dark throughout, and contain a small amount of quartz sand. The latter may have occurred in the clay naturally rather than having been added as tempering material.

Specimen *b* resembles the two preceding pieces in being very hard and dark in color, but a coarse sand or crushed quartz had evidently been added to the clay. The impression of coarsely twisted cords appears on the surface. The three pieces thus far mentioned are believed to have belonged to the same early period.

Specimens *c, d,* are fragments of coiled ware. Both are of a reddish brown color, hard and compact. The upper piece, *c,* is part

[12] Harrington, M. R., Cherokee and earlier remains on Upper Tennessee River. Mus. Amer. Indian, New York, 1922.

of the rim of a vessel, and although it suggests a bowl of large diameter, it is less than 1/5 inch thick. It bears on the outer surface the impressions of very finely twisted cords, passing in two directions and continuing over the top. The clay contains a large amount of very fine grit, which may have been natural, and also some larger pieces of crushed quartz. The lower edge, as shown in the photograph, is a concave surface extending the entire length of the sherd and is the bottom of a coil of clay applied when building up the wall of the vessel.

The lower specimen, *d,* resembles fragments of several vessels recovered from sites on the Rappahannock and Rapidan Rivers. The impression of a net is clearly defined; however, some of the strands, those on the extreme left, are not twisted but are straight. These may have been sinew or some vegetal material, but the greater part of the sherd is similar in appearance to some found at Skinkers Ford on the Rapidan,[13] which are believed to bear the impression of a textile woven entirely of loosely twisted cords made of the hair of the bison or of some other animal.

Among the bits of pottery found scattered over the site are several others bearing faint impressions of nets and some of single twisted cords, but the two specimens, *a,* are the only examples of the early ware bearing the impression of basketry. The latter are different from all others; they are harder and darker in color and are less disintegrated although believed to be the oldest. The surfaces of other small sherds are so greatly weathered and worn that it is no longer possible to distinguish any markings that may originally have been on the outer surfaces. Some bits may be fragments of smooth vessels that were never marked by cords or nets. Better examples of all types of earthenware may be preserved beneath the surface of the site.

CONCLUSION

The variety of objects found at the Mons site should be accepted as evidence that it had been frequented by man from the earliest times, and beneath its surface may be hidden conclusive proof that makers of Folsom points once occupied the valley.

As previously mentioned, certain material recovered from the site— projectile points and fragmentary pottery—is similar to that attributed to the Round Grave people of parts of Kentucky and Tennessee. In the former region these were regarded as belonging "to

---

[13] Bushnell, David I., Jr., The Manahoac tribes in Virginia, 1608. Smithsonian Misc. Coll., vol. 94, No. 8, pp. 39-40, pl. 17, *b,* 1935.

the oldest horizon in Kentucky." And in Loudon County, Tenn., the remains were the earliest of three distinct periods of occupancy recognized, the last and therefore most recent being represented by the historic Cherokee.

The occurrence at the Mons site of material similar to that attributed to the early people of parts of the country west of the mountains suggests the probability that the vicinity of the Peaks of Otter was occupied during that same period, long before the arrival of the Cherokee, who, according to their tribal tradition, once had a village near the Peaks. But others had been in the region many centuries before it was claimed by the contemporaries of the Round Grave people; these were the makers of the Folsom points, probably the first nomadic hunters to penetrate the wilderness.
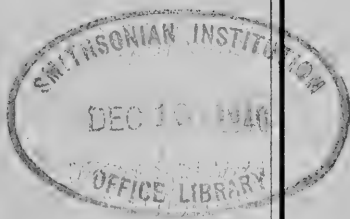
NEW FOSSIL LIZARDS FROM THE UPPER CRETACEOUS OF UTAH

BY

CHARLES W. GILMORE

Curator, Division of Vertebrate Paleontology,
U. S. National Museum

(PUBLICATION 3602)

NEW FOSSIL LIZARDS FROM THE UPPER CRETACEOUS OF UTAH

BY

CHARLES W. GILMORE

Curator, Division of Vertebrate Paleontology,
U. S. National Museum

NEW FOSSIL LIZARDS FROM THE UPPER CRETACEOUS OF UTAH

By CHARLES W. GILMORE

Curator, Division of Vertebrate Paleontology, U. S. National Museum

In 1937 a Smithsonian paleontological expedition to central Utah, under the direction of the writer, was fortunate in finding a locality rich in well-preserved and articulated skeletal remains of a new and unique member of the Sauria. Further collecting here in 1938, 1939, and 1940 by parties working under the leadership of Dr. C. L. Gazin found many additional specimens, among which were included some fragmentary remains of a much smaller but undescribed lizard.

Although these specimens are among the most ancient Sauria known from North America, they have the further distinction of being more completely preserved than any members of this suborder yet discovered on this continent.

From a study of all available materials of the first-mentioned form, practically the entire skeletal structure is now known, except the distal half of the tail. A detailed osteological description with illustrations of all important elements is given in a manuscript submitted for publication to the United States Geological Survey; but since a year or more may elapse before the published article appears, it seems desirable to prepare this preliminary paper giving the names and brief diagnoses of the new genera and species. Detailed description of the skeleton, discussion of affinities, and illustrations will appear in the more extended article.

SUBORDER SAURIA

POLYGLYPHANODON, new genus

POLYGLYPHANODON STERNBERGI, new species

FIGURE 1

Type.—U.S.N.M. No. 15477, consists of the skull, lower jaws, and many skeletal parts.

Paratype.—U.S.N.M. No. 15816, consists of a nearly complete articulated skeleton.

Type locality.—South Dragon, Manti National Forest, Emery County, Utah.

Horizon.—North Horn formation, Upper Cretaceous.

Diagnosis.—Dentition subacrodont, heterodont; 6 teeth in premaxillary, 18 in maxillary, 19 in dentary; posterior teeth much widened with sharp transverse cutting edges; upper and lower teeth indistinguishable; skull deep, strongly constructed; pineal foramen in fronto-parietal suture; premaxillary with long spine; postfrontal
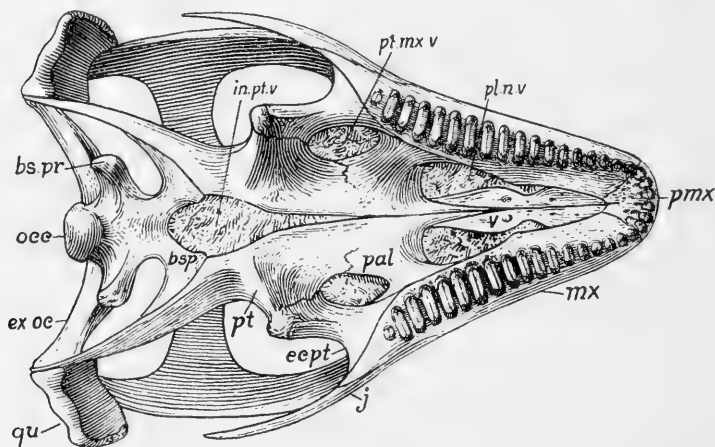

FIG. 1.—Skull of *Polyglyphanodon sternbergi*. Type, U.S.N.M. No. 15477. Palate view. bs. pr, basioccipital process; bsp, basisphenoid; ecpt, ectopterygoid; ex oc, exoccipital; in. pt. v, interpterygoid vacuity; j, jugal; mx, maxillary; occ, occipital condyle; pal, palatine; pl. n. v, palatonarial vacuity; pmx, premaxillary; pt, pterygoid; pt. mx. v, pterygo-maxillary vacuity; qu, quadrate; v, vomer. Natural size.

distinct; postorbital present; splenial extensive but falling short of symphysis; surangular and angular distinct; angular greatly restricted on external surface; vertebrae procoelus; zygosphene and zygantrum well developed; centra tapering; 29 presacrals; 2 sacral vertebrae; coracoid with one emargination; clavicles perforate; interclavicle anchor-shaped with bifurcated anterior extremity; ischium and pubis like *Iguana;* limb bones of moderate length; stout; feet typically lacertian; digital formula of manus 2, 3, 4, 5, 3; pes 2, 3, 4, 5, 4.

The unique character of the dentition is alone sufficient to distinguish *Polyglyphanodon sternbergi* from all other Sauria; its main features are clearly shown in figure 1.

PARAGLYPHANODON, new genus

PARAGLYPHANODON UTAHENSIS, new species

Figure 2

Type.—U.S.N.M. No. 15668, consists of a left maxillary containing eight teeth.

Type locality.—South Dragon, Manti National Forest, Emery County, Utah.
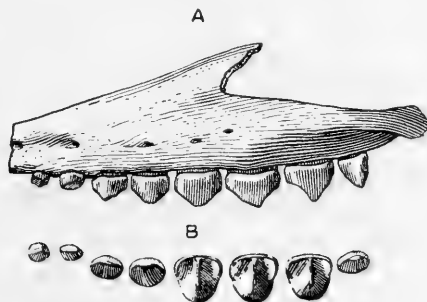
Fig. 2.—Left maxillary of *Paraglyphanodon utahensis*. Type, U.S.N.M. No. 15668. *A*, lateral view; *B*, superior view of teeth. Five times natural size.

Horizon.—North Horn formation, Upper Cretaceous.

Diagnosis.—Dentition subacrodont, heterodont; teeth short, stout, with sharp lateral and transverse cutting edges; anterior teeth reduced, with simple crowns; vertebrae procoelus; individuals small.

The principal characters of the type are clearly indicated in figure 2.

INCREASED STIMULATION OF THE ALGA STICHOCOCCUS BACILLARIS BY SUCCESSIVE EXPOSURES TO SHORT WAVE LENGTHS OF THE ULTRAVIOLET

(WITH TWO PLATES)

BY
FLORENCE MEIER CHASE
Division of Radiation and Organisms,
Smithsonian Institution

INCREASED STIMULATION OF THE ALGA STICHOCOCCUS BACILLARIS BY SUCCESSIVE EXPOSURES TO SHORT WAVE LENGTHS OF THE ULTRAVIOLET

(With Two Plates)

BY

FLORENCE MEIER CHASE

Division of Radiation and Organisms,
Smithsonian Institution

INCREASED STIMULATION OF THE ALGA STICHO-COCCUS BACILLARIS BY SUCCESSIVE EXPOSURES TO SHORT WAVE LENGTHS OF THE ULTRAVIOLET

By FLORENCE MEIER CHASE

Division of Radiation and Organisms, Smithsonian Institution

(WITH TWO PLATES)

INTRODUCTION

The stimulation of growth as measured by cell multiplication in the green alga *Stichococcus bacillaris* Naegeli has been produced by the optimum stimulative exposure of the cells to each of four short wave lengths of the ultraviolet. The optimum stimulative exposure occurs at approximately two-thirds of the lethal threshold of each of the wave lengths 2352, 2483, 2652, and 2967 A. (Meier, 1939). Since the stimulative action is not transitory but has persisted in the cells for the past 3 years, and since the stimulated cells, though slightly shorter and wider than the control cells, are also greener and in better condition, further research was undertaken, as described here, to determine the effect of successive stimulative exposures of the algal cells to each of the above-mentioned wave lengths. Irradiations of the stimulated cells and control cells were also made to ascertain the difference in their sensitivity to the lethal wave lengths of the ultraviolet spectrum.

The spectroscopic manipulations and physical measurements were performed by Dr. E. D. McAlister, of the Division of Radiation and Organisms.

LITERATURE

The investigations by other workers on the lethal and stimulative effect of the ultraviolet have been reviewed in previous papers (Meier, 1934, 1936, 1939).

I. SUCCESSIVE STIMULATION
EXPERIMENTAL PROCEDURE

A quartz mercury-vapor arc and a fused quartz prism spectrograph were used for the exposures to the wave lengths 2652 and 2967 A. A spectrograph with crystal quartz prisms served for the irradiations with the wave lengths 2352 and 2483 A. Absolute measurements of the intensity of the lines were made with a Clark vacuum thermocouple as described by Johnston and Weintraub (1939) and a double monochromator as in the method described by Brackett and McAlister (1932).

The method used for the growth and irradiation of the algal cultures has already been described in the previous paper (Meier, 1939), but for the sake of clearness and convenience it is briefly repeated here.

The unicellular green alga *Stichococcus bacillaris* Naegeli lends itself satisfactorily to precise and accurate counting and measurement because of its size and method of multiplication. This alga has an elongated cell usually varying from 1 to 2μ in width and 4 to 8μ in length. Multiplication takes place by transverse division of the protoplast that partially fills the cell and by the formation of cross walls, thus developing two cells in place of the one parent cell. The nucleus usually lies near the center of the cell. Filaments of more than two cells were rarely observed in the cultures. The alga develops rapidly, forming a green deposit in Detmer 1/3 solution.

The nutritive solution Detmer 1/3, which was used entirely for this series of experiments, was made up in the following proportions and then diluted 1/3:

Calcium nitrate	1.0	gram
Potassium chloride	0.25	"
Magnesium sulfate	0.25	"
Potassium acid phosphate	0.25	"
Ferric chloride	0.002	"
Distilled water	1.0	liter

Before irradiation, algal cells were pipetted from actively growing cultures into small quartz tubes, which were designed and constructed by L. B. Clark, of the Division of Radiation and Organisms. One side of each tube was flattened so as to insure equal and complete irradiation of the contents. Each quartz tube was equipped with a slender stirrer made of nichrome wire No. 24 inserted through the cork so that the culture could be stirred during irradiation. After the stemlike base of the tube had been securely inserted in a rubber

stopper so placed as to hold the tube directly in the monochromatic ultraviolet ray, the tube was examined with a piece of uranium glass to insure that the contents were covered by the ultraviolet ray. The quartz tube transmitted approximately 90 percent of the ultraviolet ray. A separate quartz tube was used for each exposure. Thermocouple measurements of the intensity were made before and after each experiment. The ultraviolet lamp was turned on half an hour before each experiment so that the intensity of the radiation was constant when the thermocouple measurements were made. The control cultures were treated exactly in the same manner as the irradiated cultures except that they were not exposed to the ultraviolet.

After irradiation, the contents of each tube were pipetted into a 300-cc. Erlenmeyer flask containing 200 cc. of Detmer 1/3, which had been sterilized in the autoclave at 20 pounds pressure for 15 minutes. After being thoroughly agitated, 100 cc. of the culture was poured into a second 300-cc. Erlenmeyer flask so that duplicate cultures were obtained for each exposure. The flasks were equipped with rubber stoppers, which were found to be more satisfactory than cotton plugs, previous experimentation having shown that the algae grow equally well in the rubber-stoppered flask and in the flask with a cotton plug, provided the cultures were inoculated a week or more after the flasks of culture medium had been autoclaved.

The cells of three drops of the culture from each flask were counted directly after irradiation, and the mean of the three cell counts was taken as the initial cell count. The pipette used for making the drops for the initial count was marked, cleaned with ether, and put away for use with the same culture 2 weeks later when the final count was made in similar fashion to the initial count. A separate pipette was assigned to each flask. In this manner equal size drops were obtained from each culture. The quartz irradiation tube contained generally 24 drops of inoculum, which were divided between the two Erlenmeyer flasks in the manner described above. The number of cells per drop of inoculum for each culture of the same experiment was fairly uniform. The number of cells per drop of inoculum varied in the different experiments.

To insure counting every cell in a drop, a special microscope slide was etched for the purpose by L. A. Fillmen, of the Division of Radiation and Organisms, in the following manner: The slide was coated with a thin layer of beeswax and then ruled into rectangles on the milling machine with a sharp-pointed tool. The lines were 1 mm. apart lengthwise and 4 mm. apart crosswise. The lines were

etched into the glass by placing a drop of hydrofluoric acid with a glass rod on the slide, and by spreading the drop with the glass rod into the grooves where it rested for a fraction of a minute. The acid was washed off with water, the beeswax was scraped off with a sharp flat tool, and the slide was cleaned.

The special pipettes made by L. B. Clark were drawn to a point so that a drop from each could be covered completely by a No. 2 A, ¾-inch cover glass. By using a euscope attachment to the microscope and a mechanical stage, it was a simple matter to count every cell on the slide with either the high-power or the low-power objective and a No. 5 ocular.

To arrange an ideal environment for the growth of the cultures after irradiation, an electric refrigerator was equipped with a special thermostat, which held the temperature at 24° C. during the light period and 22° C. during the dark period. Fluorescent daylight lamps were tested and proved to produce better growth conditions for the algae than varying daylight. A set of four of these 15-watt daylight lamps was installed. The lights gave an intensity of approximately 150 foot-candles on the bottom shelf and 300 foot-candles on the top shelf.

The flasks of algae were placed on the lower shelf of this chamber and illuminated for 12 hours of each 24 hours during their growth period of 2 weeks.

In the present work, cultures in which the growth of the cells had been previously stimulated by an exposure to the ultraviolet were given repeated exposures at intervals of a month or more to the same wave length. The final growth ratios are presented in tables 1, 2, 3, and 4. Since the agreement between the duplicate cultures of the individual experiments was in the same order as illustrated in table 1 which shows the complete results obtained with 2352 A., in an effort to save space, the means of the results of the duplicate cultures are given for the three other wave lengths in tables 2, 3, and 4.

To make tables 1, 2, 3, and 4 perfectly clear, the following example is given: From a control culture of algae that had been irradiated in May 1937 (see table 1), a quartz tube of algal cells was drawn for the experiment of May 1939 and then pipetted into 200 cc. of newly made and autoclaved Detmer 1/3 solution in a 300-cc. Erlenmeyer flask. After the contents of the flask had been agitated, 100 cc. of the culture were poured into a second 300-cc. Erlenmeyer flask. Cells from a culture that had been irradiated 12 minutes (the optimum stimulation time for 2352 A.) in May 1937 were poured

into a second quartz tube and irradiated for 12 minutes by 2352 A., then the cells were placed in 200 cc. of Detmer 1/3 in a 300-cc. Erlenmeyer flask and after agitation the contents were divided into a second flask. The cultures for the experiment of August 1939 were inoculated from the cultures of the experiment of May 1939, and those for the experiment of February 1940 from the ones of the experiment of August 1939. As described above, duplicate cultures were made in each instance.

TABLE I.—*Increased stimulated growth[1] resulting from repeated exposures to 2352 A.*

Exposures (minutes)				Growth ratios $\frac{S}{C}$			
May 1937 [590][2]	May 1939 [608]	Aug. 1939 [605]	Feb. 1940 [600]	May 1937	May 1939	Aug. 1939	Feb. 1940
0	0	0	0	1.0(2.6)[3]	1.0(1.4)	1.0(1.5)	1.0(1.4)
0	0	0	0	1.0	1.0	1.0	1.0
12	. . . .	. . . .	. . . .	1.7	1.6	1.6	. . . .
12	. . . .	. . . .	. . . .	1.8	1.5	1.4	. . . .
. . . .	12	. . . .	. . . .	. . . .	1.3	1.5	. . . .
. . . .	12	. . . .	. . . .	. . . .	1.4	1.6	. . . .
. . . .	12	12	. . . .	. . . .	1.9	3.1	. . . .
. . . .	12	12	. . . .	. . . .	1.9	2.9	. . . .
12	12	12	. . . .	. . . .	. . . .	3.3	. . . .
12	12	12	. . . .	. . . .	. . . .	3.3	. . . .
. . . .	12	12	12	. . . .	. . . .	3.4	3.9
. . . .	12	12	12	. . . .	. . . .	3.8	3.6
12	12	12	12	. . . .	. . . .	. . . .	4.6
12	12	12	12	. . . .	. . . .	. . . .	4.8

[1] Growth is measured here by cell multiplication.
[2] Figures in brackets =intensity in ergs/sec.cm.^{2}
[3] Figures in parentheses =growth rate of control cultures in each experiment.

TABLE 2.—*Increased stimulated growth[1] resulting from repeated exposures to 2483 A.*

Exposures (seconds)				Growth ratios $\frac{S}{C}$			
May 1939 [2620][2]	Nov. 1939 [2520]	Jan. 1940 [2480]	Mar. 1940 [2420]	May 1939	Nov. 1939	Jan. 1940	Mar. 1940
0	0	0	0	1.00(1.2)[3]	1.00(1.5)	1.00(1.8)	1.00(1.5)
30	. . . . . .	. . . . . .	. . . . . .	1.70	. . . .	. . . .	. . . .
. . . . . .	30	. . . . . .	. . . . . .	. . . .	1.60	. . . .	. . . .
30	40	. . . . . .	. . . . . .	. . . .	2.45	. . . .	. . . .
. . . . . .	30	30	. . . . . .	. . . .	. . . .	1.80	. . . .
30	30	30	. . . . . .	. . . .	. . . .	2.60	. . . .
. . . . . .	30	30	30	. . . .	. . . .	. . . .	3.16
30	30	30	30	. . . .	. . . .	. . . .	3.90

[1] Growth is measured here by cell multiplication.
[2] Figures in brackets =intensity in ergs/sec.cm.^{2}
[3] Figures in parentheses =growth rate of control cultures in each experiment.

TABLE 3.—*Increased stimulated growth[1] resulting from repeated exposures to 2652 A.*

Exposures (seconds)				Growth ratios $\frac{S}{C}$			
Dec. 1938 [1980][2]	Nov. 1939 [1970]	Dec. 1939 [1940]	Mar. 1940 [1960]	Dec. 1938	Nov. 1939	Dec. 1939	Mar. 1940
0	0	0	0	1.00(1.6)[3]	1.00(1.5)	1.00(2.6)	1.00(1.3)
40	. . . . .	. . . . .	. . . . .	1.80	. . . .	. . . .	. . . .
. . . . .	40	. . . . .	. . . . .	. . . .	1.70	. . . .	. . . .
40	40	. . . . .	. . . . .	. . . .	2.25	. . . .	. . . .
. . . . .	40	40	. . . . .	. . . .	. . . .	2.10	. . . .
40	40	40	. . . . .	. . . .	. . . .	3.15	. . . .
. . . . .	40	40	40	. . . .	. . . .	. . . .	2.35
40	40	40	40	. . . .	. . . .	. . . .	4.65

[1] Growth is measured here by cell multiplication.
[2] Figures in brackets =intensity in ergs/sec.cm.²
[3] Figures in parentheses =growth rate of control cultures in each experiment.

TABLE 4.—*Growth[1] resulting from repeated exposures to 2967 A.*

Exposures (seconds)		Growth ratios $\frac{S}{C}$	
Feb. 1939 [2370][2]	Sept. 1939 [2330]	Feb. 1939	Sept. 1939
0	0	1.00(1.5)[3]	1.00(1.5)
200	. . . .	1.75	1.55
. . . .	200	. . . .	1.55
200	200	. . . .	1.10

[1] Growth is measured here by cell multiplication.
[2] Figures in brackets =intensity in ergs/sec.cm.²
[3] Figures in parentheses =growth rate of control cultures in each experiment.

RESULTS

After four successive irradiations, the cells exposed to 2352 A. were stimulated to a growth rate of 4.7 times that of the control; those exposed to 2483 A. to 3.9 times the control and those exposed to 2652 A. to 4.65 times that of the control. Although the cells were stimulated by the first irradiation with 2967 A. to 1.62 times the control, they did not respond to the second irradiation and their rate of increase was practically the same as that of the control.

CELL MEASUREMENTS

The lengths and widths of 500 cells in a representative culture of each set of irradiated cultures, and the controls, were measured with an ocular micrometer. From these data the means of the measurements were computed and tabulated in table 5. The ratios were computed by dividing the mean length for 500 cells of the stimulated

cultures by the mean length of 500 cells of the controls. The ratios for the width were obtained in a similar manner.

A study of the table shows that the cells decrease in length with each stimulative exposure to the ultraviolet. The cells increase in width except with the final fourth exposures of 2352 A. and 2483 A. The decrease in length is to be expected since the rate of the multiplication of cells in the stimulated cultures is so much higher than in the controls that the stimulated cells do not have time to attain the length found under normal conditions before they divide to form new cells.

TABLE 5.—*Cell measurements* [1]

A.	Exposure	Mean length μ	Ratio $\frac{S}{C}$ Percent	Mean width μ	Ratio $\frac{S}{C}$ Percent
	Minutes				
2352	0	4.717	....	1.184	....
	12	4.326	91.7	1.296	109.5
	12+12	3.232	68.5	1.484	125.3
[2]	12+12+12	2.365	50.1	1.294	109.3
[2]	12+12+12+12	1.717	36.4	0.879	74.3
	Seconds				
2483	0	4.792	....	1.152	....
	30	4.589	95.8	1.412	122.6
	30+30	3.360	70.1	1.305	113.3
[2]	30+30+30	2.523	52.7	1.287	111.7
[2]	30+30+30+30	2.149	44.8	1.046	90.8
2652	0	5.178	....	1.145	....
	40	5.009	96.7	1.559	136.2
	40+40	4.230	81.7	1.614	141.0
[2]	40+40+40	3.270	62.9	1.418	124.0
[2]	40+40+40+40	2.510	48.5	1.186	103.6
2967	0	5.094	....	1.346	....
	200	5.062	99.4	1.501	111.5
	200+200	4.936	96.9	1.549	115.1

[1] The mean is of 500 cells in each case from representative cultures.
[2] Many disintegrated cells are present.

The shorter the wave length, the greater is the effect on the algal cells; for example, the cells stimulated by four exposures to 2352 A. are 36.4 percent of the length of the cells of the control, whereas those exposed four times to 2652 A. are 48.5 percent of the length of the cells of the control. The difference in decrease in size of the cells exposed to separate wave lengths indicates that each wave length has a specific effect upon the cells.

Plate 1 shows photomicrographs of representative cells from the five sets of cultures under 2352 A. The difference in size of the cells of the cultures exposed to different stimulative amounts of the ultraviolet is evident.

DISCUSSION

It will be seen by the following tabulation that the exposures to radiation were adjusted so that the stimulation of multiplication was nearly in the same proportion for all four wave lengths on first stimulation. The mean factors of multiplication in tables 1, 2, 3, and 4, control being unity, are as follows for successive equal stimulations.

Wave length, A.	2352	2483	2652	2967
Factor on 1st stimulation...............	1.54	1.65	1.75	1.62
Factor on 2nd stimulation...............	3.30	2.12	2.17	1.10
Factor on 3rd stimulation...............	3.52	2.88	2.75	...
Factor on 4th stimulation...............	4.70	3.90	4.65	...

With the exception of the fourth stimulation for wave length 2652 A. these numbers follow approximately the general law that the longer the wave length the less effective for multiplication are successive equal stimulations.

It is very interesting to compare the results with the measurements of length and width after successive stimulations. The mean factors of length and width, referred to controls as unity, are given below. The column headed "volume" is found by multiplying the lengths by the squares of the width factors.

Wave length, A.	2352			2483		
	Length	Width	Volume	Length	Width	Volume
Factor 1st stimulation...	.917	1.095	1.099	.958	1.226	1.440
Factor 2nd stimulation...	.685	1.253	1.075	.701	1.133	.900
Factor 3rd stimulation...	.501	1.093	.599	.527	1.117	.658
Factor 4th stimulation...	.364	.742	.201	.448	.908	.369

Wave length, A.	2652			2967		
	Length	Width	Volume	Length	Width	Volume
Factor 1st stimulation...	.967	1.362	1.794	.994	1.115	1.236
Factor 2nd stimulation...	.817	1.410	1.624	.969	1.151	1.284
Factor 3rd stimulation...	.629	1.238	.964	...	...	...
Factor 4th stimulation...	.485	1.036	.520	...	...	...

Here we find the product of length by width, by width, which may be regarded as a rough measure of volume, continually increasing with wave length for the stimulations except in the case of the second stimulation for 2483 A. On first stimulations the volumes, according to this rough index, are greater than those of the controls for the four wave lengths, and this is the case for the two longer wave lengths also on second stimulation. But with rapid multiplication, such as occurs at the shorter wave lengths, the volumes soon fall below the controls.

The question naturally arises whether these results are caused by selection or by fundamental modification of the organisms. In short, are these permanently changed algae to be regarded as merely selected types, or as new species? If we had only the data on multiplication to guide us, we might be inclined to the hypothesis that irradiation tended to push to the fore the stronger, hardier individuals, and to destroy the weaker ones, thus raising the ratio of multiplying, and successive stimulations were merely a repetition of this process. But with the measurements of length and width in view, we see that the greater the stimulated ratio of multiplication, the smaller and presumably weaker the individuals become, and the more and more altered their shape as measured by ratio of longitudinal and transverse axes. Since they become so much smaller, but at the same time so much more rapidly multiplying, when irradiated with the shorter, most effective, wave lengths, does it not seem to point to a deep-seated change in the organism, rather than a mere selection?

II. THE DECREASED SENSITIVITY OF STIMULATED CELLS TO LETHAL EXPOSURES OF THE ULTRAVIOLET

The research described below was undertaken with the purpose of comparing the lethal sensitivity to the ultraviolet of the descendants of the treated cells with the descendants of the untreated cells.

EXPERIMENTAL PROCEDURE

The cultures of algae had been growing since the time of irradiation each in 100 cc. of Detmer 1/3 solution in a 300-cc. Erlenmeyer flask. Each culture was poured over the surface of Detmer 1/3, 2 percent agar which had gelled over a ground glass plate (8 x 10 cm.) resting on the bottom of a large petri dish (15 cm. in diameter). The petri dishes, plates, and Detmer 1/3 agar had been sterilized previously at 20 pounds pressure for 20 minutes in the autoclave. The petri dishes were covered immediately after the cultures had been added and were then placed on a table under four fluorescent daylight lamps, each of which was 30 watts and 89.5 cm. in length, so installed as to give an intensity of 300 foot-candles on the plates of algae. The cultures were illuminated for 12 hours of each 24 hours.

After 3 or 4 days, when the algae had started to grow on the agar, the excess liquid was decanted. The petri dish cultures were then allowed to grow for about a month, when the surfaces were completely and uniformly covered with green algal growth.

The agar plate covered with green cells was then cut out of the surrounding agar in the petri dish and placed upright in a closed sterile container with a quartz window. A decker was arranged in front of the slit of the crystal quartz prism spectrograph to permit the exposure of different portions of the plate for different lengths of time. The intensities of the wave lengths are presented in table 8. When the plate was removed from the spectrograph after irradiation, it was placed in a sterile covered petri dish, where it remained for observation under natural conditions of day and night at a temperature of about 22° C.

Untreated cultures that had been inoculated at the time of the inoculation of the treated algae were poured on the agar plates and irradiated at the same time and in the same manner as the treated algae.

The cultures were observed daily after irradiation and each decolorized region corresponding to a lethal wave length was recorded as soon as it appeared.

RESULTS

The algal cultures that had been previously stimulated with 2967 A. behaved very much like their corresponding controls. The decolorized regions appeared on both sets of plates at approximately the same time.

However, the algal cultures that had been previously stimulated with 2352, 2483, or 2652 A. behaved differently from their controls. All the decolorized regions appeared more quickly on the plates of controls than on the corresponding plates of previously stimulated algae.

Tables 6, 7, and 8 show the means of days of appearance of the decolorized regions after exposure to the full short wave length

TABLE 6.—*Exposure of stimulated cultures to the ultraviolet spectrum for 5 minutes*

Radio-toxic regions[1]	Appearance of radiotoxic regions in days after irradiation of cultures previously stimulated by monochromatic ultraviolet as follows:								
	2352 A. (3)[2]	2483 A. (2)	2652 A. (3)	Average of means	Control cultures			Average of means	Ratio of means $\frac{S}{C}$
					2352 A. Group (4)	2483 A. Group (2)	2652 A. Group (2)		
A.	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	
2536	5.3	5.0	5.0	5.1	3.5	2.0	2.0	2.5	2.0
2652	4.3	4.0	5.3	4.5	3.0	2.0	2.0	2.3	2.0
2804	6.0	5.5	6.0	4.8	3.0	4.0	2.0	3.0	1.6

[1] See table 8 for intensities of radiotoxic regions.
[2] The figures in parentheses indicate the number of cultures of which the means are given.

TABLE 7.—*Exposure of stimulated cultures to the ultraviolet spectrum for 25 minutes*

Radio-toxic regions[1]	Appearance of radiotoxic regions in days after irradiation of cultures previously stimulated by monochromatic ultraviolet as follows:								Ratio of means $\frac{S}{C}$
	2352 A. (3)[2]	2483 A. (3)	2652 A. (3)	Average of means	Control cultures			Aver-age of means	
					2352 A. Group (4)	2483 A. Group (2)	2652 A. Group (2)		
A.	Days	Days	Days		Days	Days	Days		
2483	6.0	9.3	6.3	7.2	4.7	2.7	2.5	3.3	2.2
2536	5.3	3.7	5.3	4.8	7.0[3]	2.0	2.0	2.0	2.4
2576	10.0	13.0	7.0	10.0	9.0[3]	5.0	4.5	4.8	2.1
2602	20.0	9.0	8.5	12.5	3.0	7.0	6.5	5.5	2.3
2652	4.3	3.7	4.3	4.1	3.7	2.0	2.0	2.6	1.6
2699	6.3	6.7	7.0	6.7	5.5	2.7	5.0	4.4	1.5
2753	8.0	9.7	7.0	8.2	3.8	4.7	5.0	4.5	1.8
2804	4.3	4.0	4.3	4.2	6.0	2.0	2.0	3.3	1.3
2894	9.0	7.0	5.5	7.2	......	6.0	3.0	4.5	1.6
2925	......	6.0	9.0	7.5	......	6.0	5.0	5.5	1.4

[1] See table 8 for intensities of radiotoxic regions.
[2] The figures in parentheses indicate the number of cultures of which the means are given.
[3] Wild.

TABLE 8.—*Exposure of stimulated cultures to the ultraviolet spectrum for 60 minutes*

Radio-toxic regions	Ergs/sec. cm.[2]	Appearance of radiotoxic regions in days after irradiation of cultures previously stimulated by monochromatic ultraviolet as follows:								Ratio of means $\frac{S}{C}$
		2352 A. (3)[1]	2483 A. (2)	2652 A. (3)	Aver-age of means	Control cultures			Aver-age of means	
						2352 A. Group (3)	2483A. Group (2)	2652 A. Group (2)		
A.		Days	Days	Days		Days	Days	Days		
2250	214	......	6.0	16.0	11.0	6.0	6.0	3.0	5.0	2.2
2300	459	11.0	6.0	12.5	9.8	5.0	5.0	4.0	4.7	2.1
2323	235	......	6.0	18.0	12.0	5.6	9.0	2.0	5.5	2.2
2352	641	9.5	6.0	12.5	9.3	4.7	7.0	1.5	4.4	2.1
2378	1004	10.0	6.0	5.0	7.0	4.5	6.0	1.0	3.8	1.8
2399	1068	......	6.0	5.7	5.9	4.0	2.0	1.5	2.5	2.4
2447	342	13.0	7.0	......	10.0	6.0	.....	4.5	5.3	1.9
2463	444	12.0	6.0	......	9.0	5.0	.....	4.0	4.5	2.0
2483	2500	6.0	3.0	4.0	4.3	3.0	2.0	2.0	2.7	1.6
2536	7265	5.0	3.0	3.3	3.8	1.6	2.0	1.0	1.5	2.5
2576	572	10.0	5.5	7.7	7.7	4.6	5.5	4.5	4.8	1.6
2602	286	11.0	7.0	7.0	8.3	5.0	5.5	5.0	5.2	1.6
2652	6303	4.3	3.0	3.3	3.5	1.6	1.5	1.0	1.4	2.5
2699	1400	5.0	4.0	7.0	5.3	2.5	2.0	3.5	2.7	2.0
2753	1026	6.3	4.0	6.5	5.6	3.8	2.0	3.5	3.1	1.8
2804	3739	4.3	3.0	3.3	3.5	1.6	1.5	1.5	1.5	2.3
2894	1603	8.0	5.0	5.0	6.0	6.0	3.5	2.5	4.0	1.5
2925	572	12.0	6.5	6.0	8.2	6.8	3.5	4.5	4.9	1.7

[1] The figures in parentheses indicate the number of cultures of which the means are given.

ultraviolet spectrum ranging from wave lengths 2250 A. to 3130 A. on the three sets of stimulated and control plates of algae. As there were three different exposures on each plate, namely, 5 minutes, 25
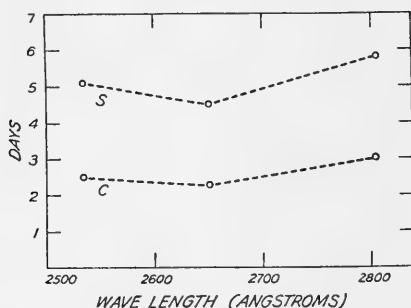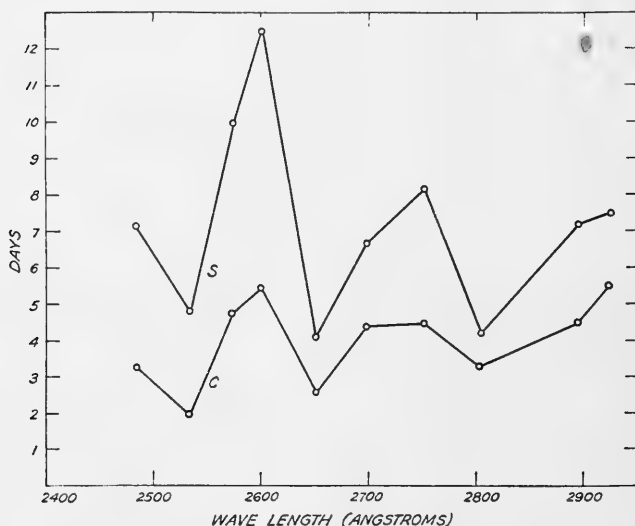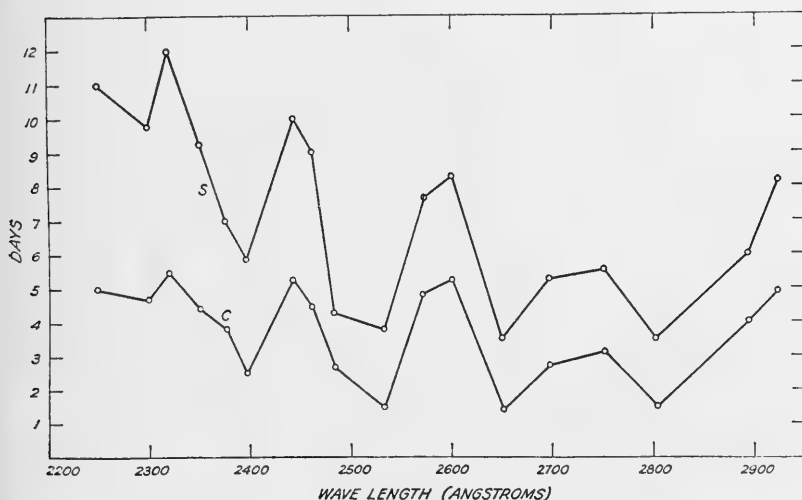

Fig. 1.—Averages of means of days of appearance of lethal regions in cultures of algae exposed for 5 minutes to the ultraviolet spectrum (based on data from table 6). S = stimulated cultures, C = control cultures.

Fig. 2.—Averages of means of days of appearance of lethal regions in cultures of algae exposed for 25 minutes to the ultraviolet spectrum (based on data from table 7). S = stimulated cultures, C = control cultures.

minutes, and 60 minutes, the results are tabulated in three separate tables according to the exposure time. Figures 1, 2, and 3 show the graphs made from the averages of the means given in tables 6, 7,

and 8. The reader's attention is drawn to the general similarity of the curve shown in figure 3 with that of figure 2 in Meier, 1936.

Plate 2 shows spectrograms of two algal plates of untreated algae and algae that had been stimulated with 2483 A. for 30 seconds. Both plates were prepared at the same time and exposed to the short wave lengths of the ultraviolet spectrum ranging from 2250 to 3130 A. for (1) 25 minutes, (2) 5 minutes, and (3) 60 minutes. Notice how much more clearly the lethal regions appear in the untreated plate than on the treated plate and also the greater number of lethal lines

Fig. 3.—Averages of means of days of appearance of lethal regions in cultures exposed for 60 minutes to the ultraviolet spectrum (based on data from table 8). S = stimulated cultures, C = control cultures.

on the untreated plate than on the treated plate, thus demonstrating the greater sensitivity of the untreated cells to the lethal regions of the ultraviolet.

The above results relate to algae that have been stimulated by one single irradiation.

More plates were made of algae that had been stimulated by 2, 3, and 4 successive exposures to 2652 A. Unfortunately, those plates which had been stimulated twice became infected with *Chlorella pyrenoidosa,* so that it was necessary to discard them. However, the means of days of appearance of lethal regions in cultures stimulated by three exposures and four exposures to 2652 A. have been sum-

marized and tabulated together with the means of the controls and single stimulative exposures to 2652 A. (from tables 6, 7, and 8) in tables 9, 10, and 11.

TABLE 9.—*Exposure of stimulated cultures to the ultraviolet spectrum for 5 minutes*

Radiotoxic regions[1]	Appearance of radiotoxic regions in means of days after irradiation of cultures stimulated by successive exposures to 2652 A. as follows:			
	Control	Exposure 40 sec.	Exposures 40+40+40 sec.	Exposures 40+40+40+40 sec.
A.	Days	Days	Days	Days
2536	2.0	5.0	6.8	6.5
2652	2.0	5.3	5.8	6.5
2804	2.0	6.0	8.0	6.5

[1] See table 8 for intensities of radiotoxic regions.

TABLE 10.—*Exposure of stimulated cultures to the ultraviolet spectrum for 25 minutes*

Radiotoxic regions[1]	Appearance of radiotoxic regions in means of days after irradiation of cultures stimulated by successive exposures to 2652 A. as follows:			
	Control	Exposure 40 sec.	Exposures 40+40+40 sec.	Exposures 40+40+40+40 sec.
A.	Days	Days	Days	Days
2483	2.5	6.3	7.0	6.5
2536	2.0	5.3	5.3	6.5
2576	4.5	7.0	21.6	14.0
2602	6.5	8.5	22.6	18.0
2652	2.0	4.3	4.8	6.5
2699	5.0	7.0	10.0	6.5
2753	5.0	7.0	17.6	8.5
2804	2.0	4.3	6.0	6.5
2894	3.0	5.5	63.0	17.5
2925	5.0	9.0	. . . .	. . . .

[1] See table 8 for intensities of radiotoxic regions.

RESULTS

In each case, the stimulated cells are less sensitive to the lethal ultraviolet than the control cells. The fact that the sensitivity did not increase in proportion with the stimulation is probably due to the number of disintegrated cells that were found in the cultures that had been irradiated three or four times.

TABLE 11.—*Exposure of stimulated cultures to the ultraviolet spectrum for 60 minutes*

Radiotoxic regions[1]	Appearance of radiotoxic regions in means of days after irradiation of cultures stimulated by successive exposures to 2652 A. as follows:			
	Control	Exposure 40 sec.	Exposures 40+40+40 sec.	Exposures 40+40+40+40 sec.
A.	Days	Days	Days	Days
2250	3.0	16.0	8.7	10.0
2300	4.0	12.5	6.0	6.5
2323	2.0	18.0	5.8	6.5
2352	1.5	12.5	4.5	6.5
2378	1.0	5.0	4.0	6.5
2399	1.5	5.7	3.8	6.5
2447	4.5	. . . .	. . . .	. . . .
2463	4.0	. . . .	. . . .	. . . .
2483	2.0	4.0	3.5	6.5
2536	1.0	3.3	3.4	6.5
2576	4.5	7.7	5.5	12.5
2602	5.0	7.0	40.8	13.5
2652	1.0	3.3	3.5	6.5
2699	3.5	7.0	4.5	6.5
2753	3.5	6.5	4.5	6.5
2804	1.5	3.3	3.5	6.5
2894	2.5	5.0	4.0	6.5
2925	4.5	6.0	7.5	8.5

[1] See table 8 for intensities of radiotoxic regions.

CONCLUSIONS

Cells of the alga *Stichococcus bacillaris* were exposed repeatedly to stimulative amounts of four short wave lengths of the ultraviolet. After four successive irradiations, the cells exposed to 2352 A. were stimulated to a growth rate (as measured by number of cells) of 4.7 times the control cells; those cells exposed to 2483 A. to 3.9 times the control cells; and those exposed to 2652 A. to 4.65 times the control cells. The cells were stimulated by the first irradiation with 2967 A. to 1.62 times the control cells, but they did not respond to the second irradiation and their rate of increase was practically the same as that of the control cells.

The stimulation of multiplication was approximately in the same proportion for all four wave lengths on first stimulation. The numbers for successive equal stimulations by each wave length followed approximately the general law that the longer the wave length the less effective for multiplication are successive equal stimulations.

The length of the cells decreased with each stimulative exposure; the width was slightly greater than that of the control cells except in the fourth stimulations of 2352 A. and 2483 A. The greater the stimulated ratio of multiplication, the smaller and weaker the indi-

viduals became and the more altered their shape as measured by ratio of longitudinal and transverse axes.

In general, the volumes continually increase with wave length for the stimulations. On first stimulations, the volumes are greater than those of the controls for the four wave lengths and on second stimulations for the two longer wave lengths. With rapid multiplication as occurs at the shorter wave lengths, the volumes soon fall below those of the controls.

The cells stimulated by monochromatic wave lengths of the ultraviolet are less sensitive to lethal exposures of the ultraviolet spectrum than are the control cells.

LITERATURE CITED

BRACKETT, F. S., and McALISTER, E. D.
      1932. A spectrophotometric development for biological and photochemical investigations. Smithsonian Misc. Coll., vol. 87, No. 12, pp. 1-7.
JOHNSTON, EARL S., and WEINTRAUB, ROBERT L.
      1939. The determination of small amounts of chlorophyll: apparatus and method. Smithsonian Misc. Coll., vol. 98, No. 19, pp. 1-5.
MEIER, FLORENCE E.
      1934. Lethal response of the alga *Chlorella vulgaris* to ultraviolet rays. Smithsonian Misc. Coll., vol. 92, No. 3, pp. 1-12.
      1936. Lethal effects of short wave lengths of the ultraviolet on the alga *Chlorella vulgaris*. Smithsonian Misc. Coll., vol. 95, No. 2, pp. 1-19.
      1939. Stimulative effect of short wave lengths of the ultraviolet on the alga *Stichococcus bacillaris*. Smithsonian Misc. Coll., vol. 98, No. 23, pp. 1-19.
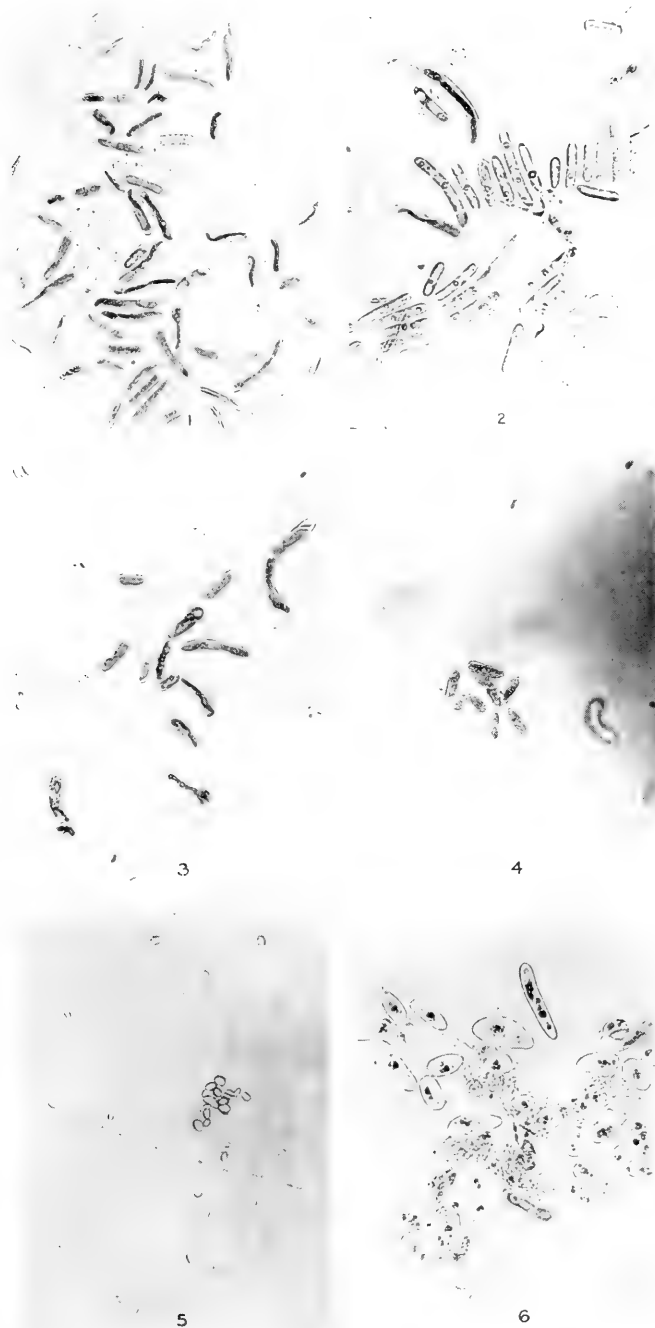
Difference in size of algal cells in cultures exposed to varying stimulative amounts of 2352 A.: 1, Control; 2, exposed for 12 minutes; 3, exposed for 12 + 12 minutes; 4, exposed for 12 + 12 + 12 minutes; 5, exposed for 12 + 12 + 12 + 12 minutes; 6, disintegrating cells exposed to 2652 A. for 40 + 40 + 40 + 40 seconds. × 250.
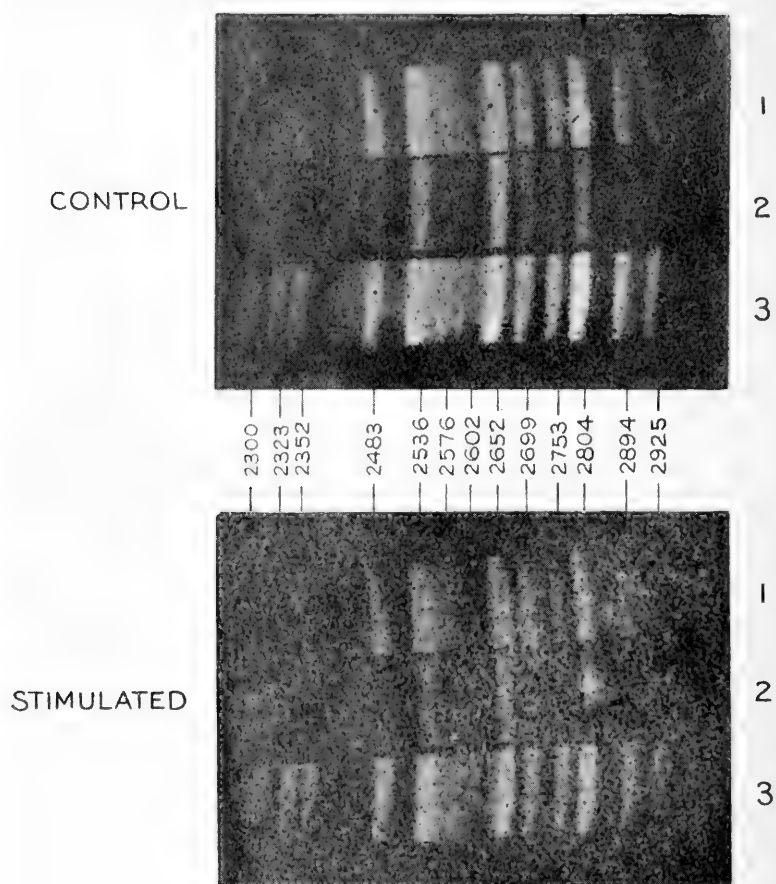
Comparative spectrograms of untreated algae and stimulated algae exposed to short wave lengths of the ultraviolet spectrum for (1) 25 minutes, (2) 5 minutes, and (3) 60 minutes.

TWO NEW RACES OF PASSERINE BIRDS FROM THAILAND

BY
H. G. DEIGNAN
Division of Birds, U. S. National Museum

.

TWO NEW RACES OF PASSERINE BIRDS FROM THAILAND

.

BY
H. G. DEIGNAN
Division of Birds, U. S. National Museum

TWO NEW RACES OF PASSERINE BIRDS FROM THAILAND

By H. G. DEIGNAN [1]

Division of Birds, U. S. National Museum

I

The orange-gorgeted flycatcher, *Siphia strophiata* Hodgson, is a regular and rather common visitor in winter to the higher peaks of western North Siam. Twenty-four specimens from Doi Angka (December), Doi Khun Tan (November), Doi Suthep (December, January, February, March), Doi Chiengdao (January), and Loi Mwe, Kengtung State (February, March) are inseparable in either sex from a series of 28 birds from the western Himalayas, Assam, Yunnan, Szechuan, and Shensi, and must be called *Siphia strophiata strophiata*.

De Schauensee [2] reported the capture of a male on Kyu Loi, Kengtung State (February) and another on Doi Suthep (December), which had "an almost entirely black throat, in the center of which is a small concealed patch of white formed by the bases of the feathers." Since then he has received a third example from Doi Pha Hom Pok (February). In the meantime, I myself took a female on Doi Suthep (November), which differs from the female of the nominate race much as De Schauensee's three specimens differ from the male of that form. I am convinced that these birds belong to a hitherto unrecognized subspecies, which may be found to breed somewhere in the Southern Shan States. For it I propose the name

SIPHIA STROPHIATA ASEMA, n. subsp.

Type—A female, U.S.N.M. No. 336545, taken at 5,500 feet on Doi Suthep, Chiengmai Province, western North Siam, November 7, 1936, by H. G. Deignan.

The type specimen differs most strikingly from the corresponding sex of both *strophiata* and *fuscogularis* (Annam) in wholly lacking a gorget. The chin, throat, and center of the upper breast are uniformly of a color which lies between buckthorn brown (Ridgway) and isabella color (Ridgway) and which changes imperceptibly into the olivaceous-brown of the sides of the breast and the flanks; all the

---

[1] Published with permission of the Secretary of the Smithsonian Institution.

[2] Proc. Acad. Nat. Sci. Philadelphia, 1934, p. 213.

feathers of the throat and breast have the concealed bases dark slate-gray and the concealed portion of the shaft white; the lores, super-cilia, ear-coverts, and sides of the neck are dark brownish slate, not pure slate-gray as in the other races. Three examples (two males, one female) of what I take to be *strophiata* in the first winter plumage are nearest to my specimen in coloration of the underparts, but all have the usual well-defined pale orange gorget with white bases of the feathers showing through.

The three adult males which presumably belong here differ from the corresponding sex of *strophiata* and *fuscogularis* in having the gorget so much reduced in area, both the orange and the white por-tions, but especially the former, that it is almost or entirely invisible until the feathers of the breast are raised.

Stresemann and Heinrich [3] have remarked on the fact that of seven females from Mount Victoria, two (one with an oviduct egg) wore the plumage of the male. Of my series of 45 sexed adults, 35 are labeled as males, 10 as females. and of these latter 5 are in male plumage. So great is the disproportion of the sexes in this series that I am inclined to believe that many of the "males" have been thus labeled by native collectors merely because of external appearances. In *fuscogularis,* 5 females are distinguishable from 2 males only by the slightly paler gray of the throat and breast.

The allegation of the "Fauna of British India, Birds" that *fusco-gularis* occurs in the Northern Shan States need be taken no more seriously than the inclusion of North Borneo within the range of *strophiata. Fuscogularis* may readily be known from *strophiata* by its having the upperparts, especially the head, more rufous-brown, less olivaceous-brown.

II

A single specimen of *Ixos mcclellandii,* McClelland's bulbul, from the mountains of northeastern Nan Province, is sufficiently distinct from any known form to justify erection of yet another local race of this plastic species. For it I propose the name

IXOS MCCLELLANDII LOQUAX, n. subsp.

Type.—An adult female, U.S.N.M. No. 350105, collected on Phu Kha, 4,500 feet, Nan Province, eastern North Siam, April 14, 1936, by H. G. Deignan.

---

[3] Mitteil. Zool. Mus. Berlin, 1940, p. 187.

The brown back separates this bird from all described forms of the species except *holtii, similis,* and *binghami.* Both geographically and in plumage it lies between *binghami* and *holtii.* From *holtii* it is separable by the much paler buffy color of the underparts and by having the bend of the wing and the under tail-coverts buffy yellow, not buff. From *binghami* it is separable by the slightly deeper buffy color of the underparts, by having the entire underparts (including the center of the abdomen) suffused with this color, and by having the bend of the wing and the under tail-coverts buffy yellow, not pale yellow.

Three forms of this species are now known from the higher mountains of northern Thailand. The green-backed *tickelli* has been taken on Doi Angka, Doi Khun Tan, Doi Suthep, Doi Rangka, and Doi Chiengdao. The brown-backed *loquax* has been found only on Phu Kha. The brown-backed *binghami* barely enters Siam on Doi Pha Hom Pok.

I have found no trace of inosculation between the brown-backed and green-backed races. *Tickelli* and *binghami* seem to be separable by no external character except color of back and each individual is definitely of one or the other form. Eight specimens from Doi Chiengdao are *tickelli;* from Doi Pha Hom Pok, the next locality to the north, De Schauensee has four examples, three of them *binghami,* the other *tickelli.* This last might represent an off-season wanderer but more likely indicates that, at the periphery of range, brown-backed parents tend to produce an occasional green-backed offspring. What seems to be an analogous case is offered by *Porphyrio albus* in Siam: where the breeding-ranges of *poliocephalus* and *viridis* meet we find, nesting in juxtaposition, blue-backed individuals which must be called by the former name, others with green backs which must be given the latter name, and apparently no examples which are not clearly of one or the other form, so far as can be judged by external characters.

Messrs. Delacour and Jabouille [4] have recently stated that *similis* is a synonym of *holtii;* this conclusion is not borne out by my material, in which seven specimens of *similis* are easily distinguishable from five of *holtii* by the deeper rufous-buff of the underparts and the darker gray of the throat.

Of the previously named forms of this bulbul, I have been able to examine *mcclellandii, tickelli, canescens, griseiventer, binghami, similis,* and *holtii,* all of which I consider valid. *Peracensis* and the recently described *ventralis* have not been available, but both differ

---

[4] L'Oiseau et la Revue française d'Ornithologie, 1940, p. 191.

widely from *loquax* in having the back green. *Ventralis,* incidentally, was apparently compared only with *mcclellandii;* nothing in the description indicates how it differs from *tickelli,* if at all.

My thanks are due to J. H. Riley, who first brought to my attention the peculiarities of the specimen that becomes the type of *Siphia strophiata asema,* and to R. M. De Schauensee and the Philadelphia Academy of Natural Sciences, who have generously sent me their valuable series of the species here discussed.

NOTES ON MEXICAN SNAKES OF THE GENUS GEOPHIS

BY
HOBART M. SMITH

NOTES ON MEXICAN SNAKES OF THE GENUS GEOPHIS

BY
HOBART M. SMITH

NOTES ON MEXICAN SNAKES OF THE GENUS GEOPHIS

By HOBART M. SMITH

The species here combined in the genus *Geophis* were distributed by Boulenger (Cat. Snakes Brit. Mus., vol. 2, 1894) in three genera—*Geophis, Atractus,* and *Dirosema.* That this arrangement cannot stand was originally pointed out by Dunn (Amer. Mus. Nov., No. 314, 1928), who refers *bicolor* and *brachycephala* directly to *Geophis,* and provisionally places *latifrontalis, longiceps, isthmicus,* and *omil-temana* in the same genus. The latter four species differ from all other *Geophis* in the possession of an anterior temporal, but this character does not, I believe, indicate closer relationship inter se than between any one of them and typical *Geophis. G. blanchardi,* for instance, very closely resembles *latifrontalis* in size, character of pattern, shape of head, and in many details of scutellation. The chief difference rests in the temporal character. *Geophis dugesii* shows a close resemblance to *omiltemana,* and in general appears more closely related to this than to *blanchardi,* which like it has no anterior temporal.

The hemipenes and maxillary dentition of *blanchardi* and *latifrontalis* are practically identical, although both differ to some extent from certain other *Geophis,* such as *semidoliatus.*

In view of these data, I cannot observe that there are characters sufficiently stable to remove any species, here referred to *Geophis,* from that genus. Accordingly I follow Dunn in placing all Dirosema (except *psephotum*) and all Mexican "Atractus" in *Geophis.*

This study was completed and a portion of the material utilized was collected during tenure of a Walter Rathbone Bacon Scholarship.

GEOPHIS CANCELLATUS, new species

Holotype.—U.S.N.M. No. 46440, female, Chicharras, Chiapas, February 1896, collected by Nelson and Goldman; paratype, U.S.N.M. No. 46441, locality not certain, but probably same as type.

Diagnosis.—Maxilla extending forward anterior to suture between first and second supralabial, a considerable distance beyond end of palatines (which extend one-third the length of the second supralabial anterior to the suture between that and third labial) ; 6 labials, third

and fourth entering eye, fifth very long and in contact with parietal; no internasals; 15 scale rows; ventrals 171; caudals 21 to 23; 28 to 32 cross bands on body, 4 to 6 on tail, not extending onto ventrals; ventral surface white.

Description of holotype.—Rostral somewhat enlarged, broader than high, scarcely pointed behind, portion visible from above measuring one-third its distance from frontal; no internasals; prefrontals much longer (3.5 mm.) than broad (2 mm.), entering orbit; frontal about as long (2.7 mm.) as broad (2.8 mm.); supraocular present, small, somewhat larger than postocular; parietals broad, more than half as wide (2.7 mm.) as long (4.3 mm.); 6 labials, third and fourth higher than long and entering eye, fifth much longer than high and more than twice as large as any other, remaining labials about as long as high; fifth labial broadly in contact with parietal; nasal divided; posterior section of nasal somewhat smaller than anterior; loreal about twice as long as broad; no preocular; 1 large temporal; 6 infralabials on one side, 8 on other; 2 pairs of chin shields, anterior separated from mental and in contact with 3 (4) infralabials, posterior pair not separated medially and about two-thirds size of anterior.

Dorsal scales in 15 rows, smooth, not pitted; ventrals 171; anal entire; caudals 23. Total length, 410 mm.; tail, 31.5 mm.

Ground color (long preserved) cream; top and sides of head dark brown, with a slightly reddish tinge; a nuchal collar, narrow medially (about 1 scale wide), laterally extending to middle of fifth labial; about 32 dark cross bars on body, 6 (including black tip) on tail; cross bars on body terminating laterally at the first scale row, all covering $3\frac{1}{2}$ to 6 scale lengths medially (except the 2 anterior, the first of which covers 10, the second 8 scale lengths); light spaces between cross bars covering 1 to $1\frac{1}{2}$ scale lengths on the middorsal line, 3 to 5 scale lengths laterally; ventral surface of tail dark brown, except near the base, where it is speckled; mental, infralabials, and anterior chin shields dark brown; otherwise ventral surfaces white.

Paratype.—The paratype shows similar scutellation of the head, except the infralabials, which are 6-7. Ventrals 171; caudals 21; female. Coloration like that of type, except cross bars somewhat broader, and less numerous (28 on body, 4 on tail). The cross bars are sometimes narrowly connected middorsally. Total length, 292 mm.; tail, 23 mm.

GEOPHIS CHALYBEUS (Wagler)

Catostoma chalybeum WAGLER, Syst. Amph., p. 194, 1830 (Mexico).

Rhabdosoma guttulatum COPE, Proc. Amer. Philos. Soc., vol. 22, p. 385, 1885 (Veracruz).

Geophis chalybeus PETERS, Monatsb. Akad. Wiss. Berlin, 1859, p. 275.

Diagnosis.—Parietal in contact with fifth labial; scales in 17 rows (or 15); a supraocular and 1 postocular; belly white (light); rostral not enlarged (less than half its distance from frontal); internasals present; scales perfectly smooth.

Range.—Known only from "Veracruz."

Remarks.—Since the time of Bocourt's Mission Scientifique au Mexique (1883), the name *chalybeus* has been applied to a Mexican species with keeled scales. I can see no reason whatever for this action, for Wagler specifically states in the original description that the scales are very smooth ("squamae notaei imbricatae, homogeneae, laevissimae"). Peters (loc. cit.) redescribes the types, which he compares with *semidoliatus,* but made no mention of keeled scales. The keels are so distinct in the Mexican keeled species, that it is not probable that both Wagler and Peters would have overlooked that character had it been present.

Although the available descriptions of the types of *chalybeus* leave much to be desired (not even the number of ventrals and caudals is known), it is surprisingly easy to allocate the name with another described species. This is *guttulatus* Cope, known from "Veracruz." The data presented by Wagler and Peters supply the following pertinent facts: (1) 6 labials, fifth in contact with parietal (eliminates *isthmicus, longiceps, latifrontalis, omiltemana*); (2) scales in 17 rows (eliminates *semidoliatus, dugesii, sallaei, petersi*); (3) a supraocular (eliminates *rhodogaster, anocularis*); (4) scales smooth (eliminates *dubius, rostralis, chalybeus* auct.); (5) dark above ("notaeo atrochalybaeo"), light below ("gastraeo flavido") (eliminates *blanchardi, cancellatus,* partly eliminates *bicolor*); (6) 1 postocular (completely eliminates *bicolor*). These characters define *guttulatus,* and cannot be construed to refer to any other species at present known.

The types of *chalybeus* were collected by Deppe, whose collections were predominantly from the Veracruz area, although some species were apparently collected elsewhere.

GEOPHIS SIEBOLDII (Jan)

Elapoides sieboldii JAN, Arch. Zool. Anat. Phys., vol. 2, pp. 21-22, 1862 ("Mexico" and "Guadalupa") ; JAN and SORDELLI, Icon. Gen., livr. 12, pl. 1, fig. 5 (well illustrated), 1865.

Diagnosis.—Parietal in contact with fifth labial ; scales in 17 rows, distinctly keeled on posterior part of body, feebly keeled on anterior part, smooth on all of tail ; dark above, light below, a row of light spots involving centers of scales of lateral dorsal scales ; portion of rostral visible from above about half its distance from prefrontals : internasals present, small ; a supraocular, 1 postocular ; scales of posterior chin shields separated medially by an azygous scale.

Range.—The type locality.

Remarks.—See remarks under *nasalis.*

GEOPHIS NASALIS (Cope)

Catostoma nasale COPE, Proc. Acad. Nat. Sci. Philadelphia, 1868, p. 131, fig. (Guatemala City).

Catostoma chalybeum SLEVIN, Proc. California Acad. Sci., ser. 4, vol. 23, pp. 404-406, 1939.

Diagnosis.—Parietal in contact with fifth labial ; scales in 17 rows, distinctly keeled on posterior part of body, feebly keeled on anterior part, smooth on posterior half of tail ; dark above, light below, no light spots in centers of scales of outer row ; portion of rostral visible from above as long as, or longer than, its distance from prefrontals ; internasals present, small ; a supraocular, 1 postocular ; scales of posterior chin shields usually in contact medially.

Range.—Definite locality records show a range from southern Chiapas to Guatemala City.

Remarks.—The removal of the name *chalybeus* from the species with keeled scales brings up the question of the identity of Cope's *nasalis,* Jan's *sieboldii,* and of various specimens reported by others as *chalybeus.* Obviously more than one species is involved, for the total range in ventral counts of the specimens referred to *chalybeus* by other authors is 116 to 154, and caudals vary from 24 to 42.

As an index to the amount of variation occurring in a single species of this complex, Slevin's counts on 217 specimens (loc. cit.) from Finca El Ciprés, Volcan Zunil, Guatemala, are invaluable. The range in ventral counts in this large series is 116 to 130, in caudals 24 to 37. I have examined two specimens (U.S.N.M. Nos. 46611, 46613) from Chicharras, Chiapas, which I believe are the same as Slevin's species, having 126 and 118 ventrals, and 31 and 33 caudals,

respectively (female, male). Certain features of the pattern and scutellation of these specimens, as well as Slevin's counts, indicate rather clearly that these are not *sieboldii,* which is described from four specimens (two from "Mexico," one from "Guadalupa," another from an unknown locality) having 146 to 154 ventrals and 34 to 38 caudals. The illustration of one of the cotypes of *sieboldii* (in Jan and Sordelli, Icon. Gen., livr. 12, pl. 1, fig. 5, 1865) shows that the rostral is very small, the portion visible from above much less than its distance from prefrontals (greater in the Chicharras specimens) ; a row of white spots in the centers of the scales of the outer row of dorsals is shown (not present in the Chicharras specimens) ; the scales of the second pair of chin shields are shown widely separated by an azygous scale (in contact in the Chicharras specimens)[1]; and the keeling of the dorsal scales terminates abruptly at the anus (continues on proximal half of tail in both Chicharras specimens).

Although I have not seen Cope's cotypes of *nasalis,* and his description does not mention all the characters above compared, the scale counts (131, 133, 134, caudals 25, 30, in three specimens), contact of the scales of the second pair of chin shields, and the larger size of the rostral, all indicate that these are the same as Slevin's series and the Chicharras specimens. The type locality also indicates the possible correctness of this conclusion.

It is impossible to allocate with these two species, *nasalis* and *sieboldii,* the specimens recorded by Bocourt (Miss. Sci. Mex., pp. 530-1, fig. 11, 1883), Boulenger (Cat. Snakes, vol. 2, pp. 318-9, 1894) and Ahl (Zool. Anz., vol. 106, p. 184, 1934). Bocourt mentions 10 specimens, from "Guatemala and Mexico," which he says have 126 to 144 ventrals, 26 to 42 caudals. The figure appears to be of a specimen of *nasalis.* Boulenger's specimens include one from Amula, Guerrero (132 ventrals, 40 caudals) and two others from Dueñas, Guatemala (138, 140 ventrals, 30 caudals, females). Ahl refers to a specimen, not described, from Xochitempa, near Chilapa, Guerrero. These Mexican specimens are arbitrarily referred to *nasalis,* in the absence of a better alternative.

KEY TO MEXICAN *GEOPHIS*

1. An anterior temporal separating parietal from labials................. 2
   No anterior temporal, parietal in contact with a labial.............. 5

---

[1] This character is subject to some variation, as discovered by Dr. Joseph R. Slevin, to whom I am indebted for data taken on his large series of this species. In 216 specimens, Dr. Slevin finds the posterior chin shields in contact (sometimes very narrowly) in 166, separated in 50.

2. Six supralabials 3
   Seven supralabials; about 40 irregular cross bars on body and tail.
   isthmicus
3. Sixth labial much the longest...............................*omiltemana*
   Fifth labial the longest... 4
4. Prefrontals much longer than broad..........................*longiceps*
   Prefrontals little longer than broad........................*latifrontalis*
5 Scales in 17 rows.. 6
   Scales in 15 rows.. 15
6. No supraoculars 7
   Supraoculars present 8
7. One postocular; ventrals 135 to 144......................*rhodogaster*
   No postocular; ventrals 124...............................*anocularis*
8. Length of portion of rostral visible from above two-thirds its distance
   from frontal 9
   Length of portion of rostral visible from above half or less than half its
   distance from frontal... 10
9. First infralabial in contact with its mate medially...............*dubius*
   Mental in contact with chin shields...........................*rostralis*
10. No internasals; reddish with black dorsal cross bands..........*cancellatus*
    Internasals present; no dorsal cross bands.......................... 11
11. Scales keeled posteriorly... 12
    Scales smooth on entire body...................................... 13
12. Scales of posterior chin shields in contact medially; scales on proximal
    half of tail keeled; length of portion of rostral visible from above
    equal to, or greater than, its distance from prefrontal..........*nasalis*
    Scales of posterior chin shields separated medially; all dorsal caudal
    scales smooth; length of portion of rostral visible from above about
    half its distance from prefrontal.......:.....................*sieboldii*
13. Diameter of eye equal to, or less than, its distance from labial border;
    3 labials in contact with anterior chin shields; belly checkered..*blanchardi*
    Diameter of eye greater than its distance from labial border; 4 labials
    in contact with anterior chin shields; belly light, sometimes black-
    spotted, tail with ventral black marks in some..................... 14
14. Two postoculars; belly spotted, subcaudals with their anterior portions
    black ....*bicolor*
    One postocular; belly and tail light, unspotted.................*chalybeus*
15. Diameter of eye greater than its distance from labial border....*chalybeus*[2]
    Diameter of eye less than its distance from labial border........... 16
16. Tail and body distinctly banded; 5 supralabials..............*semidoliatus*
    Tail not banded, anterior part of body sometimes banded; 6 supralabials 17
17. Length of portion of rostral visible from above two-thirds its distance
    from frontal ....*petersii*
    Length of portion of rostral visible from above half or less than half
    its distance from frontal... 18
18. Scales faintly keeled; no bands; ventrals 129 to 133.............*sallaei*
    Scales smooth; bands present on anterior part of body, sometimes faint;
    ventrals 150 to 164...*dugesii*

---

[2] One of the three types of *guttulatum* (=*chalybeus*) has 15 scale rows,
while the other two have 17. The aberrant specimen has short rows intercalated
between the others on various parts of the body.

FURTHER NOTES ON MEXICAN SNAKES OF THE GENUS SALVADORA

BY
HOBART M. SMITH

(PUBLICATION 3630)

FURTHER NOTES ON MEXICAN SNAKES OF THE GENUS SALVADORA

BY

HOBART M. SMITH

(PUBLICATION 3630)

FURTHER NOTES ON MEXICAN SNAKES OF
THE GENUS SALVADORA

By HOBART M. SMITH

A review of the Mexican *Salvadora* in the National Museum, originally intended to fill out data on *bairdii,* has resulted in the discovery of two undescribed forms, one of them particularly interesting as illustrating an entirely new direction of evolution in the *grahamiae* group of the genus. As might be expected, this novel species originates in an isolated area not previously known to harbor any member of the group.

In addition, a third undescribed form, closely related to another isolated species recently described, was discovered by Dr. E. H. Taylor and Richard Taylor in an area so remote from that occupied by its close relative that its existence there is most remarkable. Through the courtesy of Dr. Taylor this form also is described herein.

The systematics of *Salvadora* is a highly interesting study, largely because of the unusual multiplicity of characters. This multiplicity at first led to confusion, as for example, in the era in the 1920's when but *"hexalepis"* and *"grahamiae"* were distinguished in the checklist area. Careful study of much larger collections in recent years, however, has shown the existence of a surprising number of truly recognizable forms.

The present review was undertaken and largely completed before it was known that the genus was in the process of review by the principal student of the group. Mr. Bogert most generously cooperated with me during the completion of the study, however, furnishing data on a number of specimens, and moreover giving me the benefit of certain conclusions reached by him with many more data than I have accumulated. In all cases, however, I have adhered to my original conclusions with regard to the status of the various Mexican forms, although I am aware that Mr. Bogert will have corrections and revisions to make. For this most generous aid and cooperation I am most grateful.

I am also indebted to Dr. E. H. Taylor for loan of specimens and help with data; to Dr. Norman E. Hartweg and K. P. Schmidt for help with data and in formulating ideas; to Dr. Howard K. Gloyd for

loan of specimens; and finally to William Stickel, who has criticized the work, made various helpful suggestions, and contributed to the construction of the key. The drawings have been prepared by my wife.

The entire study has been completed during tenure of, and with greatly appreciated assistance from, the Walter Rathbone Bacon Scholarship.

SALVADORA BOGERTI, new species

FIGURES 1, 2

Type.—U.S.N.M. No. 30296, female, from "Tehuantepec," collected by François Sumichrast.

Diagnosis.—Rostral slightly enlarged, edges somewhat free; dorsolateral dark stripes terminating on nape, not divergent, not crossing temporal region; lateral dark stripe not fused anteriorly with dorsolateral stripe; 9 supralabials; 2 loreals; anterior section of nasal separated from second supralabial; frontal in contact with, or narrowly separated from, preocular; posterior chin shields rather widely separated; ventral and caudal count low.

Description of type.—Rostral somewhat enlarged, with slightly free edges; seen from the front, the sides of the rostral diverge a little; anterior edge of rostral, seen from above, nearly straight; maximum width of rostral slightly greater than its distance from frontal; length of frontal subequal to length of parietals; distance of frontal from tip of snout three-fourths its length; frontal narrowly in contact with preocular on one side, narrowly separated on other; 9 supralabials, the fifth and sixth entering orbit; anterior section of nasal separated from second supralabial; 2 loreals, the lower much the smallest and wedged between preoculars, supralabials and upper loreal; 2 preoculars; 2 postoculars; temporals $2+2+3$; seventh supralabial in contact with postoculars; 10-11 infralabials; posterior chin shields much smaller than anterior, separated from each other by a relatively large, elongate scale.

Ventrals 188; subcaudals 87, tail complete; scale rows 17-17-13; the third scale row dropped at the 117th ventral on one side, at the 116th on the other; the paravertebral rows are dropped at the 141st ventral.

Maxillary teeth $11+3$.

Total length, 463 mm.; tail length, 115 mm.

Middorsal light stripe (cream in color) one and two half-scale rows wide at nape, one scale row wide at posterior end of body, its edges rather sharply defined; dorsolateral dark stripes slate gray, covering

two and two half-scale rows anteriorly, two and one-half rows pos-
teriorly; these stripes terminate anteriorly at the nape, and do not
diverge nor pass through the temporal region; most of the scales in
the dorsolateral dark stripe have the anterolateral edge light colored
(usually concealed), while the anteromedial and posterolateral edges
are black; only the posteromedial edge is gray as the rest of the scale;
a narrow lateral dark stripe anteriorly occupies the third scale row
and the extreme outer edges of the fourth row; posteriorly (poste-
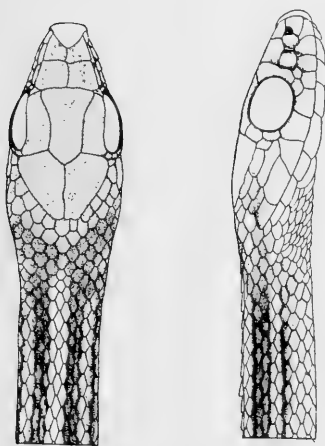
Fig. 1.—Cephalic scutellation of
Salvadora bogerti, from type.
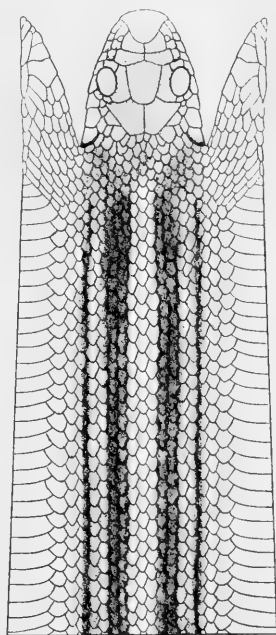
Fig. 2.—Pattern of head and
neck of *Salvadora bogerti,* from
type. Scale pattern hypothetical,
based on that of *lineata.*

rior to point at which the third scale row drops) the lateral stripe is
on the second and third rows; the lateral stripe disappears anteriorly
at the nape, and does not merge with nor approach the dorsolateral
dark stripes; posteriorly the lateral stripe disappears at the anus.
Ventral surfaces immaculate.

Comparisons.—The caudal count, number of maxillary teeth, and
several characters of the cephalic scutellation link this species with
what might be termed the *grahamiae* group, and exclude it from the
group or groups formed by the species *mexicana, lemniscata,* and

pulcherrima. However, the peculiar combination of characters possessed by it make dubious its closest relationship within the *grahamiae* group.

The locality data borne by the specimen (Tehuantepec) are not precise, but it may be assumed that the specimen was taken in some mountain range west of the Isthmus of Tehuantepec and perhaps in the area northwest of the city of Tehuantepec. It can be stated with some degree of assurance that the semiarid lowlands about the city of Tehuantepec do not harbor this species, else it probably would have appeared with the recent intensive collecting in that area.

Assuming this, it is apparent that the specimen comes from an area from which no others of the group are known. Furthermore, the mountain ranges of this area form a relatively compact group isolated faunistically and physiographically from the nearest other areas represented by specimens of the group.

Salvadora bogerti is comparable to *bairdii,* known from central Mexico as far south as southern Puebla, in two important characters: color pattern and the separation of the anterior section of the nasal from the second supralabial. The two most noteworthy similar features of the color pattern are: first, that the median light stripe narrows posteriorly to a width of one scale row; and second, that the dorsolateral dark stripes do not diverge anteriorly nor pass through the temporal region, but terminate on the nape. These two characters, held in common with *bairdii,* differentiate it from all other members of the group. The species is easily distinguishable from *bairdii* by the possession of 9 supralabials, higher number of maxillary teeth ($9 + 3$ normally in *bairdii*), enlarged rostral, 2 loreals, and probably by a lower average ventral and caudal count (the lowest counts in *bairdii* females are exactly the counts of *bogerti*).

The other Mexican species, *intermedia,* with its subspecies *richardi,* most closely situated geographically, differs widely from *bogerti* in color pattern, having the lateral stripe fused with the dorsolateral on anterior third of body, dorsolateral stripes passing through eye, a lower number of supralabials, single loreal, higher number of subcaudals, and separation of the antepenultimate supralabial from the postoculars.

From the geographically distant *lineata, hexalepis, grahamiae,* and their subspecies, *bogerti* differs markedly. *S. h. hexalepis, h. celeris,* and *h. virgultea* are the only forms of the genus normally with two loreals, and they moreover have the posterior chin shields widely separated as in *bogerti,* but from these *bogerti* may be distinguished in color pattern, the nasal-second labial character, smaller rostral, much

lower ventral and caudal count, etc. *S. h. deserticola* is perhaps more
easily comparable to *bogerti* than any other form, as the scutellation
of one is within the range of variation of the other, except for the
nasal-second supralabial character and form of rostral, but the color-
ation is very different.
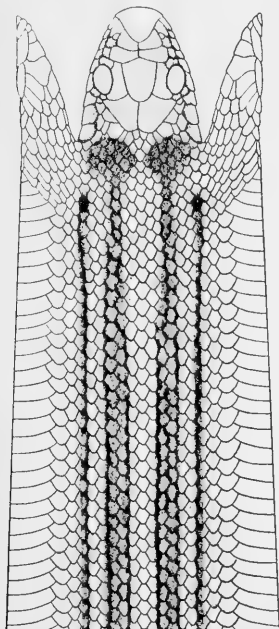
FIG. 3.—Pattern of head and
neck of *Salvadora bairdii*, from
U.S.N.M. No. 56576, Jalisco.
Scale pattern hypothetical, based
on that of *lineata*. Note great
similarity of pattern in *bairdii*
and *bogerti*, both of which have
irregular black areas in the
dark stripes.
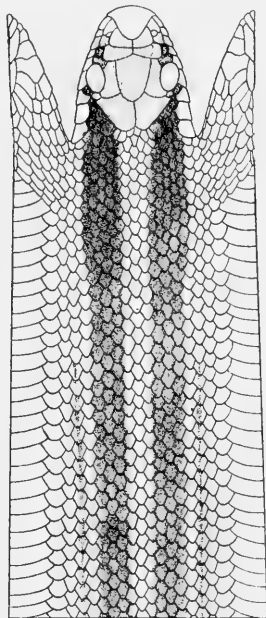
FIG. 4.—Pattern of head and
neck of *Salvadora lineata*, from
U.S.N.M. No. 105304, 17 miles
west of Santa Caterina, Nuevo
León. Texas specimens show
a greater divergence of the
dorsolateral dark stripes; the
condition as shown is more or
less characteristic of Mexican
specimens.

S. grahamiae and *lineata* are so completely different from *bogerti*
that comparisons are unnecessary.

Finally, the present specimen exhibits one character which, if found
constant in the species, occurs in no other of the group. That is the
contact or near contact of the frontal with the preocular. So uni-
versally are these scales separated in members of the *grahamiae* group
that I would consider the condition in the type of *bogerti* anomalous
if it were not for the fact that the same condition occurs frequently in
lemniscata and *mexicana*.

Within the *grahamiae* group two smaller groups are apparent—one containing *intermedia* and *hexalepis* (with their subspecies), the other containing *bairdii, grahamiae,* and *lineata*. Group I is characterized by normal possession by its members of 11 + 3 teeth and a pattern which involves fusion of the lateral stripe with the dorsolateral on the anterior part of the body. Some interesting gradations in ventral and caudal counts are apparent in this group. In group II the teeth are normally 9 + 3 or 10 + 3, and the lateral stripe, when present, remains distinct from the dorsolateral throughout its length. *S. bairdii* is by far the most distinct of group II and it is certainly the most primitive of either group, but its relationship with this group rather than with group I is apparent.

In determining the relationship of *bogerti* to these two groups, therefore, it is necessary to choose between emphasis on number of teeth, or on pattern, for the one links it with group I, the other with group II. It has been demonstrated in many groups of animals that certain details of pattern frequently are more stable than anatomical characters. I believe that this is another example of that phenomenon, since to me the pattern and geographical position of *bogerti* seem more significant and to link that species more definitely with *bairdii* than the considerable difference in number of teeth would imply.

SALVADORA INTERMEDIA RICHARDI, new subspecies

FIGURE 5

Type.—E. H. Taylor–H. M. Smith collection No. 23470, male, collected 1 mile north of Tehuacán, Puebla, August 8, 1940, by Richard Clark Taylor.

Diagnosis.—Rostral somewhat enlarged, with edges slightly free, its anterior border (viewed from above) nearly straight; 8 supralabials; antepenultimate supralabial separated from postoculars; maxillary teeth 11 + 3; lateral stripe fused with dorsolateral stripe, on anterior third of body, poorly defined; anterior section of nasal separated from second supralabial; ventrals 189 in male type.

Description.—Rostral somewhat enlarged, with slightly free edges; seen from the front, the sides of the rostral are nearly straight; anterior edge of rostral, seen from above, nearly straight; maximum width of rostral slightly greater than its distance from frontal; length of frontal subequal to length of parietals; distance of frontal from tip of snout nearly equal to length of frontal; 8 supralabials, fourth and fifth entering orbit; anterior section of nasal separated from second supralabial; 2 loreals on one side (the lower small and flat),

1 on the other; second supralabial broadly in contact with loreals; 2 preoculars on one side, 3 on other (the extra scale is split from the lower part of the upper preocular); antepenultimate supralabial separated from postoculars by a small scale; 2 postoculars; temporals 2+3 (2+2); 10 infralabials; posterior chin shields much smaller than anterior, separated from each other anteriorly by a small scale
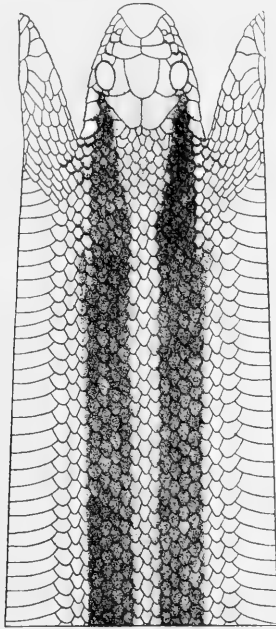

FIG. 5.—Pattern of head and neck of *Salvadora intermedia richardi*, from type. This pattern is duplicated in *i. intermedia*. Scale pattern hypothetical, based on that of *lineata*. Note similarity between this and *lineata* in character of pigmentation; both of these show the peculiar individual scale pattern on posterior part of body consisting of a white anterolateral and black anteromedial edge.

and a portion of end of an anterior chin shield, posteriorly by 2 small scales.

Ventrals 189; subcaudals indeterminate, 82 without tip; scale rows 17-17-13; third row dropped at the 115th ventral (114th on one side); paravertebral rows dropped at 122nd ventral.

Maxillary teeth 11+3.

Total length, 861 mm.; snout to vent, 657 mm.

Middorsal light stripe three scales wide at neck, gradually becoming narrower posteriorly, at posterior end of body one and two half-scale rows wide (the half-scale rows are dusky); dorsolateral dark stripes fused with lateral stripes anteriorly, the dark color extending to middle of third scale row; lateral stripe begins to show very dimly at about the 40th ventral, but only at the point at which the third row drops does it become clearly defined; posterior to this point the lateral row follows the third scale row to near the anus, where it disappears; the considerable lateral extension of the dorsolateral stripes contributes to the indistinctness of the lateral stripe; dark stripes diverging anteriorly and passing over temporal region to eye; ground color (slate gray, with a bluish tinge) extending onto ends of ventral surfaces; head somewhat brownish.

Anterior portion of belly white; edges of ventrals becoming pink in middle portion of belly; posterior third of belly light salmon pink; tail pink, becoming white toward tip (in preserved specimen).

Anterolateral edges of scales in dorsolateral stripes white, their anteromedial edges black (concealed).

Comparisons.—This form is very close to *intermedia,* agreeing with that in all pertinent details of color and pattern (including the pink belly), in form of rostral, number of labials and number of maxillary teeth. It differs from *intermedia* primarily in ventral count, the known range of variation in male *intermedia* being 175 to 181. It is impossible to state whether there are differences in caudal counts.

In the cephalic scutellation, it is most notable that the anterior section of the nasal is separated from the second supralabial in *richardi,* in contact in *intermedia;* secondarily it may be pointed out that the loreals are 1-2 and the preoculars 2-3.

These characters are very meager, but in their totality imply a significance; one or two such differences would not be notable; but the union in this specimen of so many, though minor, differences, coupled with the fact that the specimen comes from an area remote from that inhabited by *intermedia,* should be significant. Only future collecting will show whether the characters are constant.

The present specimen brings the range of *intermedia* as a whole very close to the known range of *bairdii,* which has been taken just 12 miles north of Tehuacán. The ranges of the two possibly overlap slightly in the area north of Tehuacán. However, it is very probable that, in general, *bairdii* does not extend south of Tehuacán, nor *richardi* very far north of Tehuacán, because this city coincidentally

is on the edge of a low, arid region which extends southward into the dry valleys of the Balsas Basin. The area is rugged and very dry, whereas the extensive plains north of Tehuacán are flat and become increasingly moist toward the north as elevation of the plains increases toward Puebla. It is noteworthy that, so far as is known, *bairdii* does not occur in extremely arid regions in any other part of its range. Furthermore, *i. intermedia* is confined, as far as known, to a mountainous habitat, similar in rainfall to that of *bairdii,* but isolated on all sides by extremely arid or tropical zones.

The subspecies *richardi* links *bairdii* and *intermedia* a little more closely, structurally as well as geographically. The presence in *richardi* of a higher number of ventrals, and the separation of the second supralabial and the anterior section of the nasal, are two steps toward the conditions exhibited by *bairdii,* which I consider the most primitive of the entire *grahamiae* group. It is rather obviously specialization in *i. intermedia* which produces low ventral count (lowest in the entire *grahamiae* group) and at the same time the naso-labial contact. The latter specialization is carried throughout all forms of group I, with the exception of *richardi.*

SALVADORA HEXALEPIS CELERIS, new subspecies

Type.—U.S.N.M. No. 40043, female, from San Blas, Sinaloa. Collected by J. N. Rose, March 28, 1910.

Diagnosis.—Rostral much enlarged; lateral dark stripe fused with dorsolateral at middle of neck; 9 supralabials; normally 1 or 2 loreals; ventrals 200 and 205 in known specimens; no trace of cross-barred effect in pattern. Maxillary teeth $11 + 3$.

Description of type.—Rostral much enlarged, with very free edges, its anterior margin (seen from above) nearly straight; anterior section of nasal broadly in contact with second supralabial; latter separated from loreal; 2 loreals on one side, 1 on other; 2 preoculars; 2 postoculars; 9-10 supralabials, the antepenultimate separated from postoculars; temporals irregular, $2 + 2 + 3$.

Infralabials 11-11; maximum length of anterior chin shields subequal to that of posterior chin shields; latter scales broadly separated on median line by 2 scales anteriorly, 3 posteriorly.

Dorsals in 17-17-13 rows, the third row dropped at the 131st ventral (129th on other side), the paravertebral dropped at the 158th ventral (162nd on other side); ventrals 200; subcaudals 77.

Maxillary teeth $11 + 3$.

Median light stripe three scale rows wide over most of body, one and two half-scale rows wide posteriorly; dorsolateral dark stripe covering two scale rows over most of body, only one posteriorly, its edges serrate and corresponding rather exactly to the scales in the rows it follows; lateral dark stripe involving mainly the fourth row,
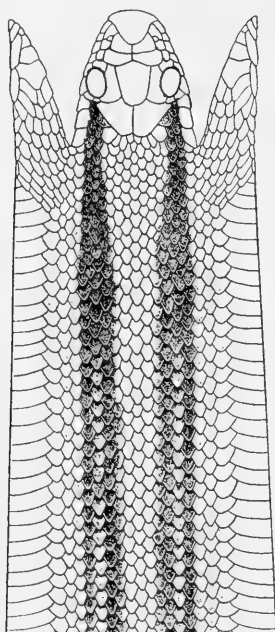
FIG. 6.—Pattern of head and neck of *Salvadora hexalepis deserticola*, from U.S.N.M. No. 22201, Ft. Huachuca, Arizona. This pattern is duplicated in *h. celeris*. Scale pattern hypothetical, based on that of *lineata*. Posteriorly the lateral line drops to the third row.
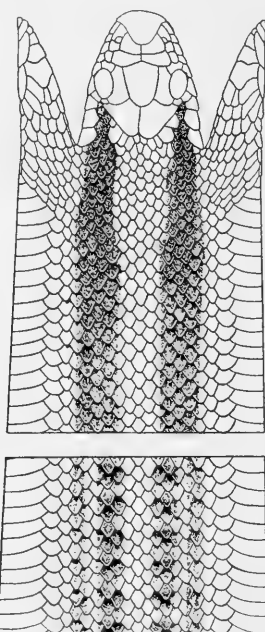
FIG. 7.—Pattern of *Salvadora h. hexalepis*, from U.S.N.M. No. 17500, Tucson, Arizona. Scale pattern hypothetical, based on that of *lineata*. Upper, head and neck; lower, middle of body. Note similarity in individual scale pattern between this and *deserticola*, both of which have the edges of the scales white, (not so in *grahamiae*, *lineata*, and *intermedia*); these two (all forms of *hexalepis*) lack the white anterolateral and black anteromedial corners characteristic of the other contrasted forms.

but also a small part of the third, on anterior part of body, descending posteriorly to the third row after loss of the third scale row anteriorly; dorsolateral stripe diverging anteriorly and passing through eye; lateral stripe fusing with dorsolateral stripe at middle of neck.

Ventral surfaces immaculate.

Comparisons.—This subspecies [1] is most closely related to *deserti-cola.* In coloration the two cannot be distinguished. Their only difference lies in ventral count, *deserticola* varying between 187 and 192 in 9 females, and from 184 to 195 in 11 males. Since these female counts average somewhat lower than males, the fact that the San Blas female has 200 is of special significance.

The only difference from typical *hexalepis* which can be stated definitely at present is in color pattern. In *hexalepis* the pattern is typically barred, i.e., there are at least alternating darker and lighter areas in the dorsolateral and lateral dark stripes. Usually the coinciding darker patches of the two stripes on a side are more or less fused into a larger, dim, dark spot or band. There is no indication of these cross bars in either *deserticola* or *celeris.*

The range of *celeris* presumably includes extreme southern Sonora as well as northern Sinaloa. The area is closely approached by *deserticola,* a specimen of which I have seen from Batopilas, Chihuahua. Mr. Bogert has kindly informed me of another specimen, also in the R. T. Moore collection (No. 17449)[2] which approaches still more closely the known range of *celeris.* This is from Yecorato, Sinaloa, which locality is probably in the same mountainous type of country as Batopilas; San Blas and Ahome are on a flat coastal plain. Intergradation of *celeris* and *deserticola* very likely occurs a short distance west of Yecorato, and very possibly *celeris* and *hexalepis* a short distance south of Guaymas, where numerous forms of mammals and lizards are known to intergrade or terminate their ranges. The line south of Guaymas is very well defined, and marks the boundary of the Arizonian and Sinaloan biotic provinces; the line to the west marks the boundary of the Durangan province, through the northern part of which the range of *deserticola* extends.

KEY TO MAINLAND MEXICAN SALVADORA

1. Lateral dark stripe involving first row of dorsal scales............... 2
   Lateral dark stripe not involving first row of dorsal scales on any part of body 3
2. Stripes continued to occiput; ventrals immaculate, 196 to 208 in number ....*lemniscata*
   Stripes interrupted anteriorly, cross bars on neck; spots on outer margins of anterior ventrals; ventrals 182 to 192 in number......*mexicana*

---

[1] Probably identical with this is a specimen from Ahome, Sinaloa, in the collection of R. T. Moore at the California Institute of Technology (No. 17943). C. M. Bogert has kindly given me data on this specimen, which has 205 ventrals, 2 loreals, 9 supralabials (fifth and sixth entering eye).

[2] Bogert informs me that this specimen has 190 ventrals and 1 canthal.

3. Only one pair of dark stripes on body, these not involving third row of
    scales on any part of body.. 4
    Stripes involving third row of scales (figs. 2, 3, 4, 5, 7).............. 5
4. Antepenultimate supralabial separated from postoculars; maxillary teeth
    11+3; stripes involving third and fourth rows of scales, bifurcated
    posteriorly (dorsolateral and lateral), but not well defined.......... 5
    Antepenultimate supralabial usually in contact with postoculars; maxil-
    lary teeth usually 10+3; only dorsolateral stripes present, well defined,
    not involving either the third or the fourth scale rows anteriorly...
                                                            g. grahamiae
5. Dorsolateral dark stripes terminating on nape and not passing through
    temporal region (figs. 2, 3)...................................... 6
    Dorsolateral dark stripes diverging on neck and passing through tem-
    poral region to eye (figs. 4 to 7)................................. 7
6. Loreals 2; rostral with slightly free edges, anterior margin (seen from
    above) nearly straight; maxillary teeth 11+3; 9 supralabials (figs. 1, 2).
                                                            bogerti
    Loreal 1; edges of rostral not free, its anterior margin (seen from above)
    distinctly convex; maxillary teeth usually 9+3; usually 8 supralabials
    (fig. 3) ....*bairdii*
7. Lateral dark stripe fusing with dorsolateral dark stripes on neck
    (figs. 5, 6, 7).. 8
    Lateral dark stripe distinct and separate from dorsolateral throughout
    its length, generally disappearing free on neck, rarely discernible to
    temporal region (fig. 4)...........................*grahamiae lineata*
8. Rostral strongly enlarged, with prominently free edges; 9 supralabials
    or more; antepenultimate labial generally in contact with postoculars..10
    Rostral moderately enlarged, with somewhat free edges; 8 supralabials;
    antepenultimate labial usually separated from postoculars............ 9
9. Anterior section of nasal in contact with second supralabial; ventrals
    182 or less...*i. intermedia*
    Anterior section of nasal separated from second supralabial; ventrals
    190 in single specimen (fig. 5)......................*intermedia richardi*
10. A distinct barred effect in pattern; lateral stripe fused with dorsolateral
    over all of neck (fig. 7)..................................*h. hexalepis*
    Pattern not barred, the stripes uninterrupted in intensity; lateral stripes
    fused with dorsolateral over anterior half or third of neck (fig. 6)....11
11. Ventrals 195 or less (fig. 6)................................*h. deserticola*
    Ventrals 200 to 205 (in two specimens)........................*h. celeris*

A NEW SHIPWORM FROM PANAMA

(WITH ONE PLATE)

BY

PAUL BARTSCH
Curator, Divisions of Mollusks and Cenozoic Invertebrates
U. S. National Museum

A NEW SHIPWORM FROM PANAMA

(With One Plate)

BY

PAUL BARTSCH

Curator, Divisions of Mollusks and Cenozoic Invertebrates
U. S. National Museum

A NEW SHIPWORM FROM PANAMA

By PAUL BARTSCH

Curator, Divisions of Mollusks and Cenozoic Invertebrates,
U. S. National Museum

(With One Plate)

In a sending of mollusks received from Dr. James Zetek for determination, there is a remarkable new shipworm, second in size of the American shipworms only to *Bankia* (*Nausitoria*) *dryas* Dall.

I take pleasure in bestowing the name of the discoverer upon this species.

BANKIA (NAUSITORIA) JAMESI, new species

Plate 1

Shell very large, subglobular, color of the anterior and anterior median exterior parts pale rose, where not stained with rust color; the rest rust-colored. The anterior part is provided with the usual sinus and reflected callus; the latter is separated from the denticle-bearing part by an impressed groove. The anterior part bears 47 finely denticulated dental ridges, which are much more distantly spaced on the early part than on the later. The individual denticles are separated by deep grooves on each side of the dental ridges. The dental ridges of the anterior median part join those of the anterior part almost at right angles; they are separated by a mere impressed line, and bear large and broad denticles. There are 36 of these dental ridges in the line continuing the basal margins of the anterior part. The middle portion of the median part is comparatively narrow and slightly concave and rather rough, while the posterior portion of the median part is broad, convex, and marked by incremental lines. The posterior part forms a semioval auricle. The interior is white. The umbones, though badly eroded, bear a strong knob from which a slender, thin, narrow blade extends almost to the basal knob. The suture, joining the anterior and median part, is thickened and somewhat rough. The middle of the median part is impressed, rough, and bears at its basal extremity a strong rounded knob. The posterior part extends over the median as a shelf and is transversely fluted on its outer half. The pallets are very large; the stalk is very long and cylindrical; the

blade is plumelike, wider on one side than the other, covered on the outside by a strong periostracum. Where the outer layer is broken away, the elements composing the blade become apparent. These might be said to be pygostyled fused joints.

The type, U.S.N.M. No. 513762, was collected by James Zetek at Balboa near the drydock in waters of the Bay of Panama. It measures: Height, 12.2 mm.; length, 12.0 mm.; diameter, 13.6 mm. The pallets measure: Length, 36.0 mm., of which 21 mm. belong to the stalk; greatest diameter, 5.0 mm.

The species is most nearly related to *Bankia* (*Nausitoria*) *dryas* Dall. It is readily differentiated from that by its smaller size, larger auricle, and, comparatively speaking, larger pallets.

SHELLS AND PALLETS OF JAMES' SHIPWORM

THE ICE AGE PROBLEM

BY

WALTER KNOCHE

Chief, Section of Climatology
Department of Meteorology, Hydrology, and Geophysics
Ministry of Agriculture, Republic of Argentina

THE ICE AGE PROBLEM

BY

WALTER KNOCHE

Chief, Section of Climatology
Department of Meteorology, Hydrology, and Geophysics
Ministry of Agriculture, Republic of Argentina

THE ICE AGE PROBLEM

By WALTER KNOCHE

Chief, Section of Climatology
Department of Meteorology, Hydrology, and Geophysics
Ministry of Agriculture, Republic of Argentina

In a paper entitled "Ice Ages"[1] Sir George Simpson argues, in opposition to the hypothesis that a decrease of radiation would produce an ice age, that, on the contrary, an increase of radiation would produce such an effect. Simpson explains this paradox clearly in a few printed pages. It seems that Simpson did not know of a brief essay by the present writer,[2] who advanced a similar opinion. The writer, however, finds the ice age question rather more complicated, and concludes that ice ages may by no means be set parallel with pluvial ages, and furthermore, that ice ages are possible by warming as well as by cooling. H. H. Clayton also made the same suggestion.[3] From this it follows that a simultaneous ice age for the whole earth is not admissible.

Let us briefly consider as an example possible situations in the Cordilleras of the western coast of South America (Chile) up to the Antarctic. If we suppose, in illustration, an average warming everywhere of 5° C. above the present normal year temperatures, the following situation would probably result: the actual temperature of approximately 18° C. at sea level in the Tropics would rise by our hypothesis to 23° C. The decrease of temperature with increasing altitude may be 0.5° C. for every 100 meters. In this case we should find 0° C. at a 4,600-meter altitude. In the Southern Hemisphere even altitudes of 6,000 meters in the Tropics (Puna de Atacama) are free from eternal snow; and only south of the Tropic of Capricorn do we find light formations of firn which lead to a strong glaciation in the Aconcagua Massif. But with the assumed temperature increase the insignificant precipitation of our days would give place, according to the arguments

---

[1] Simpson, Sir George, Ice ages. Ann. Rep. Smithsonian Inst. for 1938, pp. 289-302, 1939.

[2] Knoche, Walter, Eiszeit durch Erwaermung der Erde. Deutsch-chilenische Monatshefte, vol. 11, Santiago de Chile, 1932.

[3] Clayton, Henry Helm, Solar activity and long-period weather changes. Smithsonian Misc. Coll., vol. 78, No. 4, p. 6, 1926.

of Simpson as well as of Knoche, to an increase of precipitation, above all in the High Cordillera. Such increase of precipitation would be near the Equator in summer (confines of Argentina-Chile-Bolivia) but farther south (latitude Valparaiso-Santiago) in winter. However, in altitudes above 4,600 meters the precipitation would fall as snow. In the peak region of the high volcanoes or high mountain chains of the Chilean-Argentine Atacama, little hanging glaciers would probably be formed, while, for example, the glacier tongues of the Aconcagua Massif would advance up to the central Chilean longitudinal valley.

In the indicated regions we ought to consider, moreover, that radiation would be diminished under the influence of increased cloudiness (see Knoche and Simpson) and therefore also the process of melting away would be more or less strongly hindered. Passing over now to West Patagonia, we have at a certain latitude average annual temperatures of 6° to 9° C., which, with a general temperature increase, according to the above-mentioned hypothesis, would give 11° to 14° C. So we should find the 0° C.-isotherm at 2,200 to 2,800 meters. Today, the firn region in northern Patagonia descends in the south to 1,600 to 1,200 meters and in Fuegia to 1,000 meters or less. The inland ice is to be found, taking no account of several mountain massifs (Cerro San Valentin), in altitudes which lie below 2,800 meters. Under the actual temperature conditions, the precipitation falls as snow even in northern West Patagonia only in altitudes above 1,600 meters, in the south above 1,200 meters, in Fuegia above 1,000 meters. With the supposed warming, the firn region of present times would receive only rain, perhaps more than the actually measured amounts. This increase is not certain because it is doubtful if the west-to-east circulation on which the West Patagonia precipitation depends would be preserved in the same strength. If the west-to-east circulation decreased, a local diminution of rainfall might occur even in a generally pluvial age.

The almost total cloudiness, which is today between 8 and 9, and consequently also the radiation, can hardly experience any essential change. The "Patagonian" conditions of West Patagonia, Fuegia, or similar regions of the earth (for example, New Zealand), are very special ones, marked by cool summers and warm winters. At the mouth of the Straits of Magellan the annual average minimum of temperature is hardly below 5° C., and snowfall at sea level is the rare exception. However, the glaciers descend to the sea owing to the colossal firn masses, and this in a latitude corresponding to that of the northern Adriatic. The glacier tongues lie in the middle of a nearly tropical, seemingly virgin forest with tree ferns, bamboo

grasses, fuchsias, and evergreen beeches. Under our assumed con-
ditions this thick forest type would cover Fuegia to the extreme south,
owing to the temperature rise and, after the disappearance of the firn,
occupy also the heights of the Cordilleras in West Patagonia.[4] The
arguments about West Patagonia refer naturally to the western as
well as to the eastern side of the Andes, as the glaciers of the two
flanks have their origin in the so-called inland ice. An increase of
5° C. in the average temperature of West Patagonia seems by no
means exaggerated when we consider that at the lighthouse of
Evangelista (western mouth of the Strait of Magellan) the annual
average was 5.6° C. in the year 1925, and the average minimum 3.6° C.
In the year 1934, however, these values were 8.4° and 7.7° C.,
respectively.

Simpson and Knoche are surely right in supposing that with a
warming, combined with increased evaporation, cloudiness, and pre-
cipitation, the average annual temperatures of the polar regions,
Arctic as well as Antarctic, would remain under all circumstances
far below 0° C., even with a general warming of more than 5° C., so
that the ice masses in the polar and subpolar regions would have to
increase. Both authors argue that the contrast, Tropics-Poles, would
be greatly enhanced. Owing to geographical differences between the
northern and southern polar regions, we ought to expect with warmer
conditions an extended ice covering in the Northern Hemisphere with
its deep Arctic sea (compare fig. 5 in Simpson's paper), while in the
Antarctic continent there would only be an extension in the dimen-
sions of the firn region a little more northward. As contrasted with
the north polar region, where in consequence of the increased ice
masses up to relatively great distances, advancing glaciation would be
plausible, such an intense cooling by the southern ice mass, in spite
of its growing, would be hardly conceivable on a great scale. Of
course, the pack-ice belt would extend itself, and the icebergs would
increase in quantity and dimension, but they would also begin to
melt away faster in the oceans of the then warmer climate of the
tropical and subtropical zone. As today on a small scale at sea level

---

[4] Prof. F. Reichert, who at the beginning of 1940 crossed the Cordilleras
of West Patagonia in the region of Mount Valentin in the middle of the
inland ice, told me that during the last 20 years there was formed in a little
"sierra" a rich vegetation of *Nothofagus*. Rats and some kinds of birds have
come there, and there exists also a small lake not in a frozen state. Twenty
years ago the same "sierra" was a complete desert with the exception of one
kind of lichen. This proves a change of climate in West Patagonia with an
inclination to warmer conditions. Therefore the inland ice may be actually
considered as a sort of "fossil" ice.

the virgin forest embraces the glacier tongues of West Patagonia, so the pack ice, in the assumed case of a planetary warming, would lie out at sea before the virgin forests of Fuegia. Even if the increase of 5° C. for Fuegia would be diminished a little by the Antarctic ice belt, the conditions could not be essentially changed. It is conceivable, as indicated above, that the general warming of 5° C. would be exceeded in Fuegia. For South Fuegia there is at present an average annual temperature of 5° to 5.5° C., and the minimum lies indeed at nearly 1° C. In the mountains of this group of islands, a temperature increase of 2° to 3° C. would be sufficient to cause the glaciers to decrease or even disappear through decrease or disappearance of firn region.

A cooling would have a reverse effect. As through lack of precipitation no firn zone exists today in the most arid Puna regions, no change would be produced by increased lack of precipitation; the desert steppe of the Puna would be transformed with all its elevations into a desert. Where little firn zones with hanging glaciers or peak glaciers exist today, these would disappear owing to the diminution of precipitation. Such glaciers now appear only in altitudes above 5,000 meters, where even today the precipitation falls in solid form. They would retreat as in the Aconcagua region.

What effect would a cooling then have in the region of the West Patagonian Cordilleras? We have here, according to isolated existing observations, even at sea level total precipitations of 2½ to 6 meters per annum, which for certain elevations may surely be doubled. It is quite possible that at some time precipitations will be found there which will equal the highest observed anywhere in the world, if indeed they will not surpass them. Let us suppose, although it is not absolutely sure, that with the then existing circulation conditions, precipitation suffers a decline, so that, contrary to the situation today, it will prevalently fall in solid form with a decline of 5° C. of the average temperature. This we suggest in Fuegia at sea level, and at nearly a 500-meter altitude above sea level in the north of the West Patagonian Cordillera. Under these conditions we must admit an ice age in Patagonia. In the polar regions, and therefore also in the Antarctic, there would be produced a decrease of the glaciation. For here only solid condensation would fall just as in our times, but in decreased quantity over the planet as a whole because of decrease of evaporation and cloudiness. The radiation in the region of the central Andes of Chile and Argentina with diminished cloudiness further tend to accelerate the decline of the glaciers. In the south an increase of the radiation could scarcely be expected, because here, owing to the

geographical conditions and to the prevailing winds, a sensible decrease of the cloud amount, which now reaches in the peak region nearly 10, is out of the question.

Summing up our considerations, it follows that the question of ice ages is a 0° question; that is, it depends on whether the precipitation, on an average, falls as snow or rain. The 0° C.-isotherm depends, however (disregarding regional and local conditions) on latitude and altitude. The latitude (neglecting the altitude) is above all decisive for the polar caps, the altitude (neglecting the latitude) for mountains—supposing that certain general morphological conditions exist, as, for example, the arid regions, windward flanks, etc.

From these examples we come to the conclusion that in certain regions of the earth, according to given conditions, at moderate altitudes with sufficient quantities of precipitation and an equilibrium between snow and rain, cooling could produce an increase of glaciers or an ice age by augmentation of solid condensation. In other zones, i. e., in very great heights with more or less solar radiation for other reasons, even in relatively adjoining regions the contrary process must be caused. In these zones, as a consequence of general warming, firn and glaciers will be formed when the "cordillera" reaches such a great altitude that solid condensations predominate. A period of warming, on the other hand, would be generally identical to a pluvial age; as we mentioned before, ascending temperature augments evaporation, cloudiness, and precipitation. According to the arguments, a pluvial age is identical with an ice age, and in certain zones, with warming. Moreover, the cooling that may cause the "West Patagonian" ice age is combined with a general reduction of precipitation; thus, not all ice ages correspond to pluvial periods.

It is furthermore probable that in some mountains the glaciers of closely adjoining peak regions can advance or retreat, according to their height and situation, either with a general decrease or with a general increase of the temperature of the earth's atmosphere. In every case, one should take care not to consider the ice ages in the north of the Northern Hemisphere as generally valid for all regions of the earth.

EVIDENCES OF EARLY OCCUPATION IN SANDIA CAVE, NEW MEXICO, AND OTHER SITES IN THE SANDIA-MANZANO REGION

BY

FRANK C. HIBBEN

University of New Mexico

WITH APPENDIX ON

CORRELATION OF THE DEPOSITS OF SANDIA CAVE, NEW MEXICO, WITH THE GLACIAL CHRONOLOGY

BY

KIRK BRYAN

Harvard University

(WITH 15 PLATES)

(PUBLICATION 3636)

EVIDENCES OF EARLY OCCUPATION IN SANDIA CAVE, NEW MEXICO, AND OTHER SITES IN THE SANDIA-MANZANO REGION

BY

FRANK C. HIBBEN
University of New Mexico

WITH APPENDIX ON

CORRELATION OF THE DEPOSITS OF SANDIA CAVE, NEW MEXICO, WITH THE GLACIAL CHRONOLOGY

BY

KIRK BRYAN
Harvard University

(With 15 Plates)

FOREWORD

Foremost among those to whom the writer is indebted are the students who gave unstintingly of their time and abilities without compensation. Among those who worked in Sandia Cave are: Mary Dalby, Margaret Young, Henry Robertson, Anne Dietz, Jean Cady, William Witkind, Adolph Bitanny, Robert Sieglitz, Ruth Smith, Martha McNary, Julian Olmstead, Adger King, Dan McKnight, Barbara Clark, Louise Diltz, Mary Ann Garrett, Mary K. Higgs, Mary Lehmer, Jane Olson, Ernst Blumenthal, James Spuhler, Carroll Burroughs, Robert Ariss, Charles Lange, James Greenacre, Robert Easterday, and Gordon Page.

Wesley Hurt aided in locating Folsom material in the vicinity of Albuquerque and Manzano. Robert Bell photographed the excavations and Charles Kepner helped in the final photographing and cataloging of the artifacts. Robert Jones and Robert Sieglitz were the surveyors and engineers and Robert Lister the draughtsman who plotted the many sections and maps in their final form. Wesley Bliss, then at the University of New Mexico, excavated the Davis Cave and aided the writer in the initiation of the excavations of Sandia Cave itself.

The author is especially indebted to Prof. Kirk Bryan, Department of Geology and Geography, Harvard University, for the working out of the geologic aspects of Sandia Cave and for advice and suggestions on the interpretation of the information obtained in the excavations.

Acknowledgment is gratefully made to Dr. E. B. Howard, University Museum, Philadelphia, for many suggestions and ideas and for help in excavating Sandia Cave; to Dr. Chester Stock, California Institute of Technology, for coming from Pasadena to examine a hearth and some material in situ and for contributing valuable data from his great knowledge of Pleistocene fauna; to Donald Scott, Dr. Earnest A. Hooton, Dr. Helmuth de Terra, Dr. Stuart Northrop, and Dr. W. W. Hill for suggestions and comparative information offered when they visited the site during excavation.

Dr. Frank H. H. Roberts, Jr., Bureau of American Ethnology, Smithsonian Institution, assisted in the interpretation of the artifacts and stratigraphy of Sandia Cave, especially in the matter of comparisons with the Lindenmeier site. Frank M. Setzler, Head Curator of

the Department of Anthropology, United States National Museum, contributed by aid and encouragement during the excavation and the preparation of the report. Dr. C. L. Gazin, Division of Paleontology, United States National Museum, and Dr. Bertrand Schultz, Museum of the University of Nebraska, identified the bulk of the specimens of faunal material from Sandia Cave.

Dr. Donald Brand, University of New Mexico, helped immeasureably with the many details involved in an excavation, and by his remarkable forebearance when the cave interfered with the writer's regular university duties. O. Fred Arthur, Supervisor, Cibola National Forest, showed gratifying interest throughout the progress of the excavations and aided in obtaining the permits that made them possible. Joseph Berman, Ceramic Laboratory, W. P. A. project 23676, University Museum, Philadelphia, made the analyses of the yellow ochre from Sandia Cave.

Not the least among those who made the investigations possible are Dr. E. G. Conklin and the other officers of the American Philosophical Society, who generously granted funds for the completion of the excavation.

<div align="right">FRANK C. HIBBEN.</div>

CONTENTS

ILLUSTRATIONS

PLATES

                             TEXT FIGURES

                               APPENDIX

EVIDENCES OF EARLY OCCUPATION IN SANDIA CAVE, NEW MEXICO, AND OTHER SITES IN THE SANDIA-MANZANO REGION

By FRANK C. HIBBEN

University of New Mexico

(WITH 15 PLATES)

INTRODUCTION

As Roberts has pointed out (1940, pp. 51, 52), it is only within the last few years that the scientific vogue has again turned to the investigations of early man in the New World. An increasing series of significant discoveries has built up incontrovertible evidence that man was present in the New World in the late Pleistocene period.[1] Only recently has the accumulated evidence reached the summary or bibliographical stage (Roberts, 1940, pp. 100-109; Sellards, 1940), although even this is still in its rudimentary form. The sum of this evidence indicates the following points:

1. That human beings were present in the New World in the latter portion of the Pleistocene period.

2. These early American inhabitants existed on a hunting type of economy.

3. Large mammals which they hunted and with which their remains are associated are now extinct.

4. These hunters were coincident with the closing phases of a glacial period known in North America as the Wisconsin.

5. Some tools, notably projectile points, made by these early men are distinctive and may be recognized out of context.

6. Geologic and stratigraphic evidence indicates that this Paleo-Indian existed at least 10,000 years ago and was distinct from and earlier than New World cultures with an agricultural and economic basis.

Evidence also indicates as extremely probable but not absolutely certain:

1. That this Paleo-Indian was physically a modern type.

2. That he may be regarded as a legitimate progenitor, at least in part, of the modern American Indian.

---

[1] See bibliography in connection with Roberts, 1940, pp. 109-116.

3. That he transmigrated in a hunting status from Asiatic sources via Bering Strait and the so-called Inland Corridor.

4. That this migration took place in Upper Paleolithic times as measured by European standards and terminology.

Obviously, one of the major problems to be solved, and certainly the most outstanding lacuna in the chronology of the New World, is the lengthy period of time between the early Paleo-Indian on the one hand and the so-called later cultures on the other, for instance the Basket Maker of the Southwest. Ever since the discovery of Folsom Man (Brown, 1929; Bryan, 1937; Cook, 1927; Figgins, 1927; Roberts, 1935, 1939, 1940), this gap has been apparent. It seemed probable that certain discoveries already made and certain sites already known would fill this gap as soon as adequate correlative material could be obtained. Signal Butte (Strong, 1935, pp. 224-236) was offered as such a possibility, but has not wholly fulfilled the requirements. Central Texas contains much material which may bridge this gap, although it has not yet done so. Recent discoveries in the trans-Pecos region (Albritton and Bryan, 1939) are especially indicative of an eventual post-Folsom chronology. The University of Arizona and Gila Pueblo have recently evolved a chronological sequence in the southern portion of Arizona,[2] which follows the Cochise finds and leads through nonpottery cultures up to and including pottery and agriculture.

The excavation of Sandia Cave unfortunately does nothing to improve our knowledge of the period between Folsom man and the earliest Basket Maker remains. Instead, the sequence established in the cave has indicated another and older type of culture, also with a hunting economy, preceding that of Folsom man. A tentative sequence, obtained from other caves in the Sandia-Manzano region, indicates post-Folsom cultures, especially those characterized by a projectile point that has been called the Gypsum Cave type. The chronology thus far found in the Sandia region, however, is early when regarded from the Basket Maker-modern Indian viewpoint and does not yet lead directly to later cultures.

Sandia Cave itself was first brought to our attention by Kenneth Davis, of Albuquerque, who had explored several caves in the region. He brought in to us, from Sandia Cave, some Pleistocene faunal material, notably a sloth claw which aroused our interest in the site. We are much indebted to Mr. Davis for his continued efforts and

---

[2] Antevs, 1937a, 1937b, 1938. Dr. Haury and Mr. Sayles have kindly outlined this sequence for the writer, although it is not yet in print.

interest in cave work in the region, and in recognition thereof, one of the caves of the Sandia group, Davis Cave, was named after him.

Even before the visit of Mr. Davis to Sandia Cave, certain Boy Scouts, especially of Troop 13 of Albuquerque, had made exploring trips through it. It was at this time (1927-1928) that they dug large quantities of the recent fill from the front of the cave, mainly to permit them to crawl farther back, and also dug one hole through the underlying calcium carbonate crust at our present meter-7 line. The hard nature of the underlying deposits, however, apparently discouraged them from looking any farther for treasure. Evidence of their digging, in the form of match sticks and other debris, was found in and around this hole.

The University of New Mexico began excavations in the cave in 1936 under the direction of the writer. As funds for excavation were not immediately forthcoming, the efforts during the first year were sporadic and exploratory. Enough evidence was gained, however, to warrant further excavations, and these were carried on, although not continuously, during the seasons of 1937, 1938, and 1939.

In the spring and summer of 1940 excavation was further facilitated by a generous grant from the American Philosophical Society. This not only permitted further digging with an increased staff, but especially made possible the installation of complete dust-removal equipment to eliminate one of the major hazards of the Sandia excavation. Yellow ochre, which pervades the cave in all but the very lowest strata, had rendered work extremely difficult and was chiefly responsible for its sporadic nature. As this yellow ochre has a basis of quartz, silicosis was an ever-present possibility and cumulative effects from exposure to it were noticed in all the workers.

Aided by the rapid progress made possible by the Philosophical Society grant, the excavations of 1940 completed the major portion of the cave deposits pertinent to the history of man. In addition tests were made throughout the length of the cave, as well as in other caves, to check the stratigraphic sequence.

THE CAVES AND OTHER SITES

Sandia Cave (fig. 1) is one of a group. There are five such holes or cavities in the Pennsylvanian limestone in the immediate vicinity, all of which show some degree of human habitation. Only two of these are of any considerable size—Davis Cave, some 45 meters to the north of Sandia Cave, and Guano Cave, still farther to the north. All the caves in the Sandia group were dug and tested extensively

with a view to corroborating the Sandia material. Both the larger caves, Davis and Guano, have a small vestibule in the fore part, with a mass of detritus, fallen rock, and calcium carbonate accumulation completely blocking the passage a short distance within. No real attempt was made to break through this blockade, as was done in
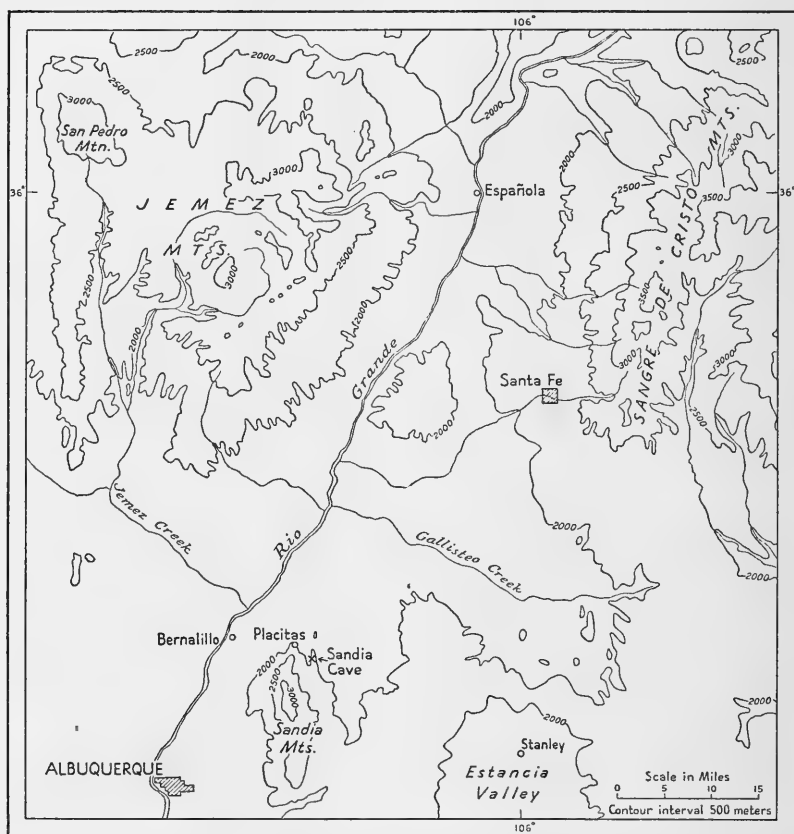

Fig. 1.—Map of part of central New Mexico showing location of Sandia Cave and relation of Sandia Mountains to the Jemez and Sangre de Cristo Mountains of the southern Rocky Mountain system. Redrawn from U. S. Geological Survey Base Map of New Mexico (Darton).

Sandia Cave, although in Davis Cave one small inner room was reached. The chief importance of the other caves in the group lies in the fact that the stratification is the same as in Sandia Cave, indicating apparently similar conditions. None of the test holes in the other caves of the Sandia group gave evidence of human material in the Pleistocene levels. Faunal material of late Pleistocene type was

present in small quantities in the layers corresponding to the Sandia stratification.

The limestone strata, which form the entire east slope of the Sandia Mountains, contain many other holes and cavities, some of which approach true cave proportions. A few of these occur in Las Huertas Canyon and in the smaller canyons to the east. There is an especially large one just below the old Ellis ranch near the head of Las Huertas Canyon. Other small caves occur in the many canyons extending eastward along the flanks and foothills of the Sandia Range. All of any size indicate human occupation, for the most part sporadic and late. Late Pueblo glazes, Tewa polychrome, and the as yet unclassified Spanish Pueblo wares are common. Occasionally, earlier material is found, such as the prayer plumes in a coiled basket, probably dating from Pueblo III, found by Vance Davis, formerly of the University of New Mexico. To date, however, there are no evidences of stages earlier than this in the Pueblo series.

The Manzanita and Manzano Mountains continue to the southward of the Sandia Range, with the same geologic formation and apparently the same general conditions as in the Sandias. The Pennsylvanian limestone on the eastern slope is more folded in some instances and more horizontal in others than in the Sandias. The limestone, however, provides excellent conditions for caves. Many such caves are known, and undoubtedly there are many yet to be found. In general, in this survey, caves high in the mountains were ignored or left for future investigation. Those low on the slopes seemed to offer the best possibilities for early man. All indications of the earliest phases of human occupancy in the region of the Sandia Mountains have been found in caves of the Upper Sonoran zone or lower.

In the region near the small town of Manzano, just north of Mountainair, are a number of limestone caves, some of which are large. These have been only sporadically tested at the present writing, but they seem to offer possibilities for further information on the question at hand. A disturbing circumstance, however, is that most of the group are wet, and stalactites and stalagmites are still actively forming. This may be because the caves are low down on the flanks of the mountain where moisture, following the cleavage lines of the Pennsylvanian limestone, drains into rather than away from them. Test pits in three of them indicate extremely interesting material of possible post-Folsom date, as discussed in subsequent pages. Two Sandia-type points have also been found by local people in caves in the Mountainair region. This whole territory gives promise of additional and vital information.

The Manzano group of caves lies only a few miles in an air line, 3 or 4 miles in most instances, from the beach terraces of Pleistocene Lake Estancia to the east, which is supposed to coincide with the pluvial period indicated by the famous Black Water Draw, between Clovis and Portales, and other late Pleistocene evidences of a moister climate. The shore area of such a body of water as Lake Estancia probably would have been important to hunters in late Pleistocene times. That such was the case is substantiated by the finding of eight Folsom points on or near the beach levels in the vicinity of Manzano and Punta de Agua close to the cave groups. No definite Folsom site has been discovered here, however. Pleistocene bones, especially mammoth, are common in the vicinity of Punta de Agua. They occur just beneath a layer of alluvium on top of a bed of reddish clay. The clay, which changes to a bluish hue in some places, outcrops on the edges of many arroyos and benches in the region. A complete but disarticulated mammoth was excavated by the expedition near the ruins of Quarai.

Twenty miles due east of Sandia Cave, near the small town of Stanley (fig. 1), a Folsom site occurs on a terrace above one of the lake beds of the Galisteo Basin. These lakes, like Lake Estancia, are also correlated with the pluvial period and presumably would have attracted Pleistocene mammals and the men who hunted them. This is an open "blow-out" site and, in addition to Folsom objects, also displays later Plains material scattered over its surface. Although several typical Folsom points have been found here (see pl. 6, *e, f*), the site is relatively useless for chronological purposes. Its sole interest in this connection lies in the fact that it is the closest Folsom site to Sandia Cave. Sporadic Folsom points have been found throughout the Galisteo area, where there are evidences of a number of Pleistocene ponds and small lakes.

Interesting and possibly significant deposits lie 6 miles to the east of Bernalillo and 5 miles down the canyon from Sandia Cave. They are known as the Placitas deposits and have been worked as a geologic problem for some years under the direction of Dr. Stuart Northrop, of the University of New Mexico.[3] Although the small town of Placitas (fig. 1), around which the deposits lie, is considerably above the level of the Rio Grande Valley, the sediments are undoubtedly slack-water depositions. The body of water, presumably Pleistocene in date, responsible for them could never have been very large. As a

---

[3] The author is indebted to Dr. Stuart Northrop for the geologic and paleontologic information on these deposits.

result of the cutting of a large arroyo, extremely deep exposures have been made, permitting thorough study of these sediments. In the bottom of this wash or arroyo, residents of Placitas found two un-grooved Folsom-shaped points similar to those from Sandia Cave. They presumably washed out of the Placitas deposits. Fire areas, usually accompanied by sporadic chips of flint, are fairly frequent at several levels in the Placitas sediments. Most of these burned areas occur at a depth of some 9 feet below the present surface on what appears to be an old soil level or stratum darkened by vegetable material. Robert Ariss, of the Department of Geology of the University of New Mexico, has recovered a variety of Pleistocene remains from these deposits including horse (probably *Equus excelsus*) and mastodon (*Mamut americana*). Again, present interest in the Placitas sediments lies in the fact that they are close to Sandia Cave and indicate relatively early occupation of the area.

The location of Sandia Cave in relation to other sites containing similar material is of extreme importance with respect to its place in general late Pleistocene history. The nearness of classic Pueblo and Folsom sites is also significant in spite of the fact that the Sandia region is peripheral to the Plains area.

Sandia Cave

Sandia Cave is located on the east side of Las Huertas Canyon at the north end of the Sandia Mountains (fig. 1). The latter are a part of a great uplift just east of Albuquerque, which runs from the Sandias on the north to the Manzanitas and the Manzanos on the south. Canyon de las Huertas follows a fault line almost due north through the Magdalena limestones of the Sandia Mountains in the vicinity of the small town of Placitas. Here the mountains descend to a series of rugged foothills. In this area the Magdalena group of Pennsylvanian limestones is dominant. The underlying granitic rocks of the Sandia upthrust do not appear, and the overlying Manzano group and red beds do not figure except considerably east of the Las Huertas Canyon area. The Las Huertas fault is the largest of several secondary faults which mar the east slope of the Sandia range (Ellis, 1922).

The country to the east of Las Huertas Canyon falls off rapidly by easy stages to the foothills bordering the Galisteo Basin and the Estancia Valley. Las Huertas Canyon and Sandia Cave are more readily accessible from the east or northeast than from the west.

Sandia Cave and the others in the group lie entirely in the Upper Sonoran zone of vegetation, although a few transitional tree species extending below their legitimate zones occur in the creek bed of Las Huertas Canyon. The talus slope below the cave is covered with pinyon and juniper. Occasional patches of scrub oak occur in the canyon bottom. A clear and permanent trout stream makes Las Huertas Canyon one of the most desirable in all of the Sandia area.

Canyon de las Huertas, or Canyon of the Gardens, is precipitous on its eastern side where Sandia Cave is located, and rises somewhat gradually on its western side, for the most part following the slant of the limestone beds (see fig. 5, p. 12).

As noted previously, Sandia Cave is the most extensive cavity in the Sandia group. In general dimensions, it is tunnellike, with a length of 138 meters and an average diameter of 3 meters, although this diameter is affected by certain sections of the cave where pipes and fissures lead from the roof to a considerable height (see fig. 3, p. 11). The actual cave extends somewhat beyond the 138-meter mark, and by squeezing, a particularly adventurous person may go several meters farther. The end of the cave is pinched off by a considerable rock fall. As no advantage apparently could be gained by going farther, this stricture was not forced by the expedition. From its mouth, the cavern drops with the dip of the limestone strata in which it is located. This formation dips toward the east at an angle of 9 to 15 degrees, and the trend of the cavern is downward with this strike. In the 138 meters of actual length, the cave drops evenly to 22 meters below the mouth at the farther end.

Prof. Kirk Bryan suggests that in Pleistocene times this long corridorlike cavity may actually have had a much larger, cavernous mouth. There is considerable evidence to support this supposition. The cliff upon which it opens has obviously weathered back in comparatively recent times, taking sections of the cave mouth with it. Cultural material within would, in many cases, appear to have slid or worked down from a former habitation level in the front of the cave that has since disappeared.

The mouth of the cave (pl. 1) at present is some 3 meters above a small ledge from which it can be reached by means of a ladder. No animal of any size could have entered it in recent years. Today there is no evidence of any ledge or natural entrance, although one supposedly was present at one time. Nor is there evidence of water or moisture having entered the cave at its mouth at any time since its formation. The cave is now absolutely dry except at the extreme eastern or inner end, where a slight dampness occurs.

The Magdalena limestone in which the cave is formed is a hard, sometimes crystalline material containing large numbers of crinoids in the cave area. Indeed, crinoid stems from the surrounding limestone are common in the cave fill. The limestone in the cave area is generally massive, but with cleavage lines natural to this formation and dipping eastward with the general strike of the beds. Sporadic cherty concretions jut out from the wall of the cave (pl. 2, fig. 1, above framework). Some are sufficiently siliceous so that they break with a conchoidal fracture. A considerable portion of the artifacts from Sandia Cave were apparently made from these cherty concretions gathered locally. Iron nodules occur in the limestone, in some places in considerable quantities. Just above Guano Cave, one of the Sandia group, an old prospect hole was dug to explore iron deposits of this nature. The presence of these iron concretions in the limestone undoubtedly correlates with the deposition of the yellow ochre, so important in the cave stratigraphy (see p. 15).

Stalactites and stalagmites are few in the cave, although some activity of this sort is evident. Deposits of cave travertine are limited almost entirely to sheet formations flowing down the walls and thence over the surface of the cave floor. These calcium carbonate sheet formations are an important factor in the history of the cave.

Once the mouth is gained, Sandia Cave is easy to enter at the present time. Here and there throughout its length, however, to make progress one must crawl or even squirm between the tops of the piles of recent accumulation and the roof (pl. 2, fig. 2). There is ample evidence that at least once during its existence and possibly on several additional occasions the opening was completely closed. When originally discovered by Boy Scouts, the entrance back of the vestibule (pl. 2, fig. 1) was entirely blocked. Certain of the strata, such as the yellow ochre and the travertine crust discussed subsequently, give evidence of having been deposited when the cave had no outside entrance.

EXCAVATION PROCEDURE

Excavation necessarily started at the mouth or west end of the cave and proceeded eastward. All measurements were made in meters and subdivisions thereof and were recorded in permanent bench marks, triangulation points, stations, and individual meter sections placed in plaster of paris on the cave roof. Minor subdivisions, artifact locations, and lesser items pertinent to the survey were marked in paint.

Transit and level were used throughout, all measurements and levels being based on station 1 (see fig. 2) just inside the cave entrance.

Excavation proceeded in meter sections, each level of each section being removed separately. As the stratigraphy proved to be distinctive, each stratum of each meter was readily segregated. In sections of special interest, excavation was by one-half or one-quarter of a meter at a time. Owing to the general solidity of the deposits below the topmost layer of recent accumulation, which was of dustlike consistency, comparatively perpendicular faces could be maintained.

The calcium carbonate crust, the deposits of Folsom age, and in some cases the yellow ochre stratum, necessarily had to be removed by forcible means. Miner's picks (pl. 3, fig. 1), geologist's picks, and frequently sledge hammers were the order of the day. As a consequence occasional specimens were fractured and many were not discovered in situ, but came to light only when lumps of cave breccia were disintegrated in the laboratory or put through a screen. The positions of cultural and paleontological specimens of special importance observed in place were carefully determined by means of the transit.

All the material from each meter or subdivision thereof, and from each stratum, was carried to the mouth of the cave in wheelbarrows and there screened, the lumps of breccia being broken up. A number of specimens came to light in this manner. Their locations can only be listed by stratum and meter.

In addition to the excavations at the mouth of the cave, a considerable portion of the fill was dug from meters 72-83 some distance back from the entrance (see fig. 2). This section seemed promising, as there was almost no modern accumulation on top of the calcium carbonate, but only one artifact, a large blade, was found in the whole section. Numerous test holes were also made in various places, as may be seen on the accompanying plan of the cave, for the purpose of checking the stratigraphy. Most of the excavations were carried to bedrock. In the rear of the cave there were some exceptions, noted on the vertical plan (see fig. 3), where large fragments of fallen rock interfered with such procedure.

Electric torches were used to light the cave, as all forms of acetylene equipment tended to clog with dust. Dust removal equipment consisted of a gasoline engine powering a centrifugal blower, an arrangement with steel-ribbed rubber exhaust and intake hoses, built by Dr. Victor Smith, of Sul Ross State Teachers College at Alpine, Tex., in accordance with certain ideas of cave excavation outlined by Frank M. Setzler.

VIEW OF SANDIA CAVE FROM TALUS BELOW CLIFF. SAFETY
SCAFFOLDING SHOWS IN CAVE MOUTH

1. Sandia Cave Entrance at Narrowest Portion back of
Antechamber

2. In Front Sections of Sandia Cave Debris is Piled Almost
to the Roof

1. At Work on Test Hole in Sandia Cave

2. Section of Deposits at Meter 20 Showing Stratigraphy

Travertine crust appears just above the shoulder of the figure; yellow ochre
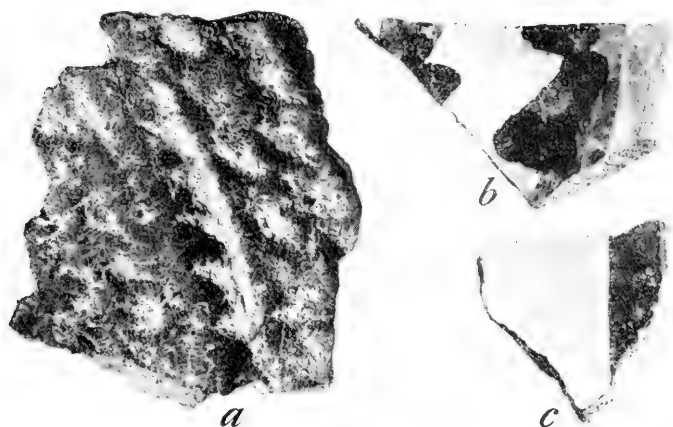stratum by the left hand.

1. FOLSOM BLADE IN PLACE IN THE CAVE DEBRIS

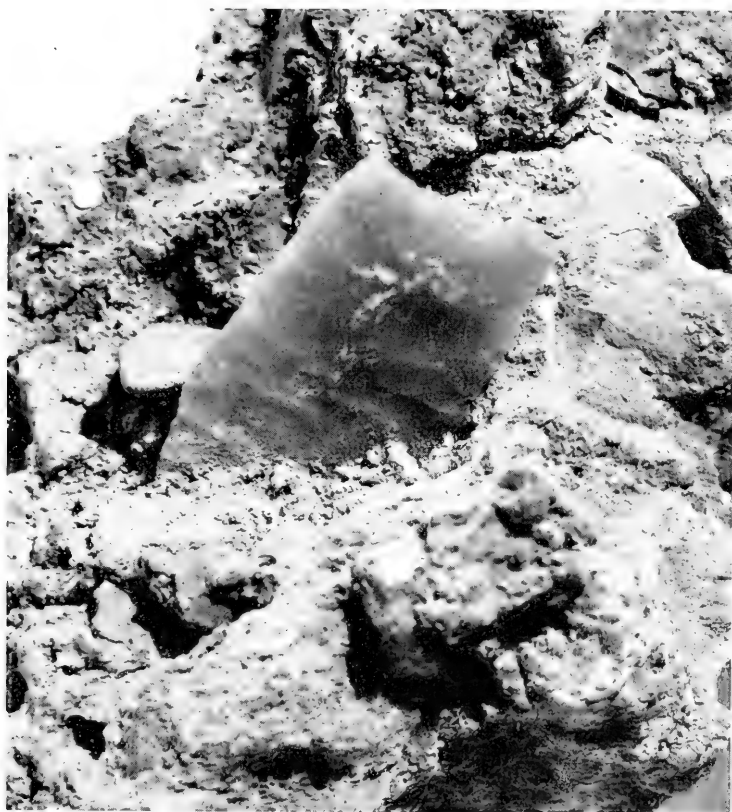A horse tooth is located just left of the trowel.

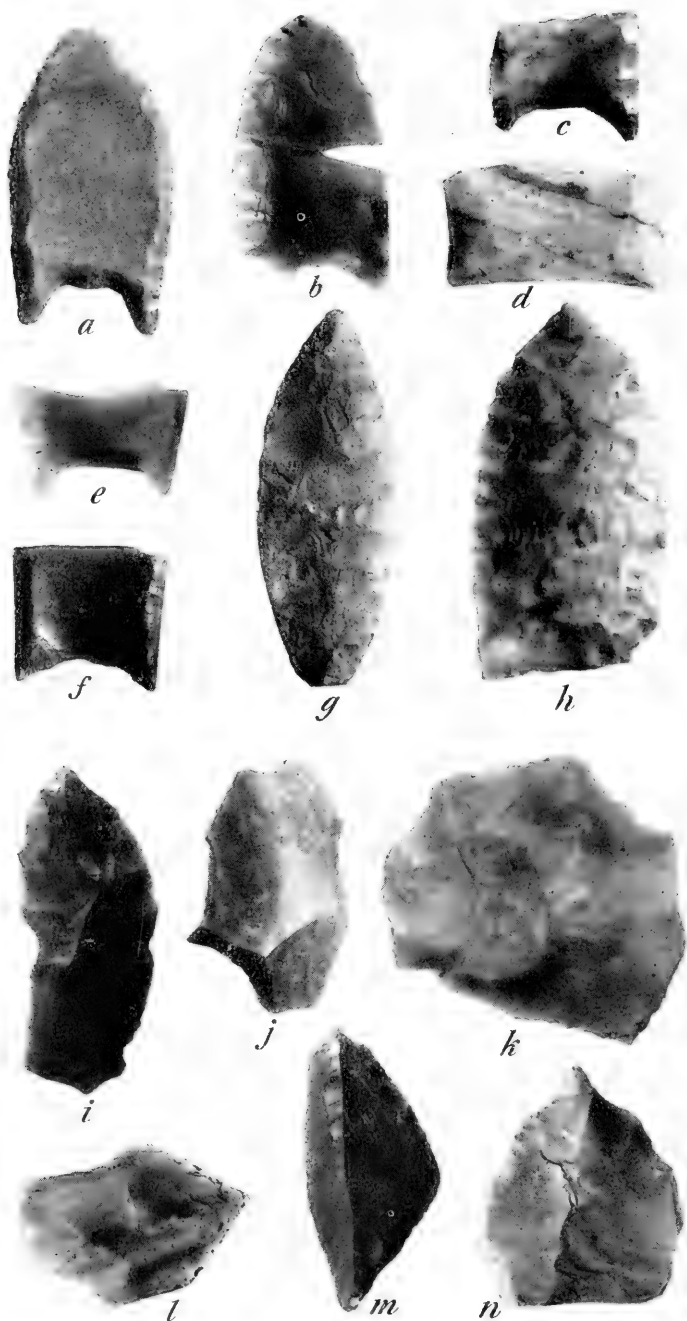2. SANDIA POINT IN PLACE AT ONE EDGE OF CAVE CHAMBER

Deposits here are thin with yellow ochre, Folsom breccia, and travertine crust appearing above.

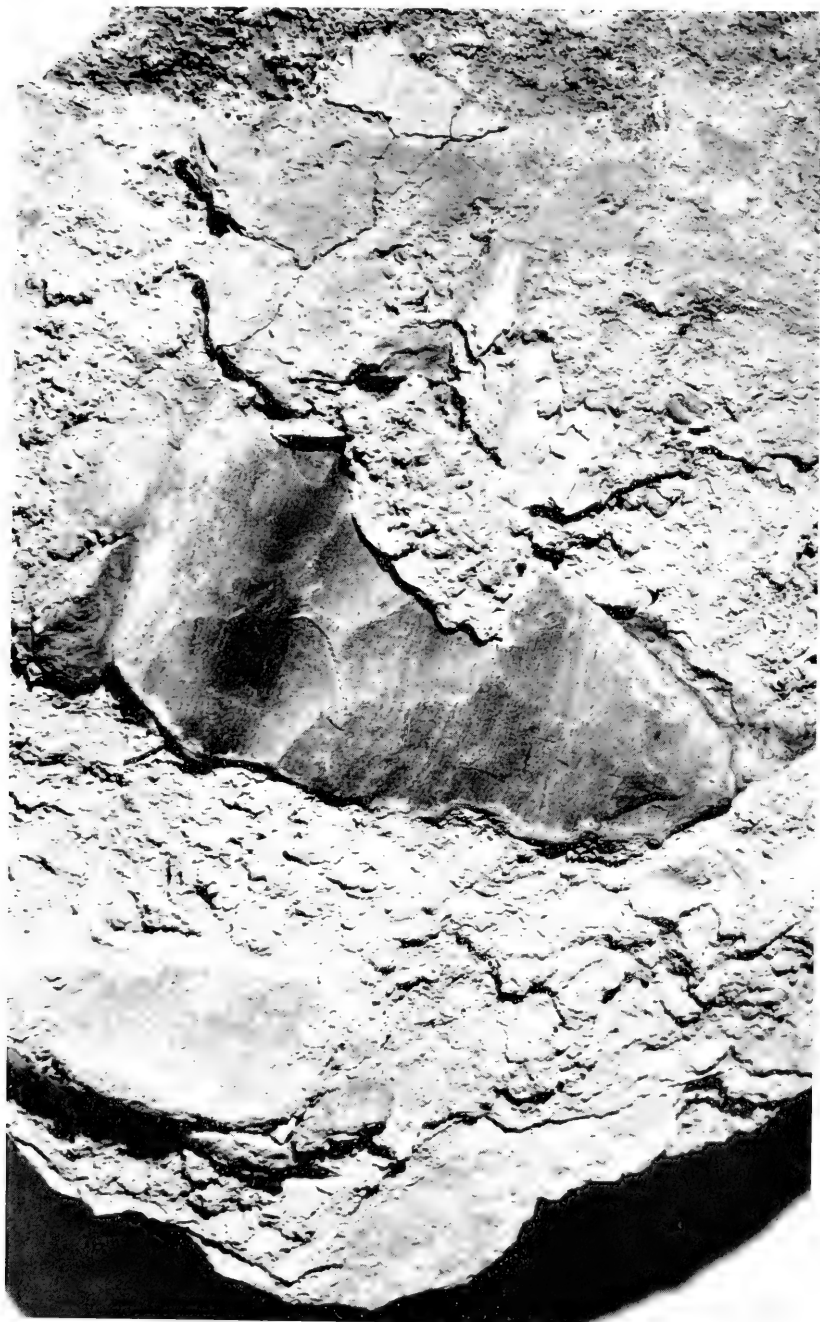1. Pueblo Utility and Glaze-ware Sherds from Recent
Layer in Sandia Cave

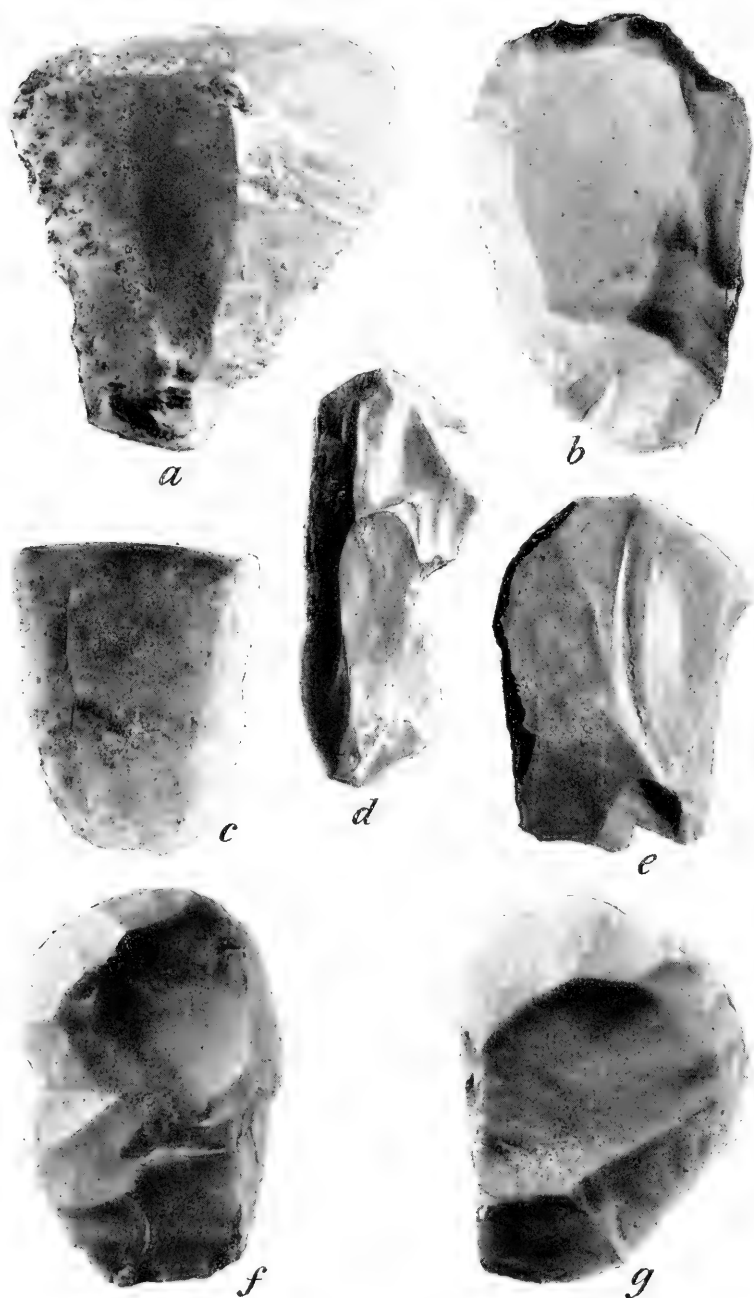2. Unfluted Folsom-shaped Point Embedded in Debris
from Sandia Cave

ARTIFACTS FROM SANDIA CAVE AND SURFACE SITE NEAR STANLEY

a, b, c, d, Folsom points and bases from Sandia Cave; *c, f,* bases from surface site near Stanley; *g, h,* other points from Folsom level; *i-n,* gravers from Folsom level.

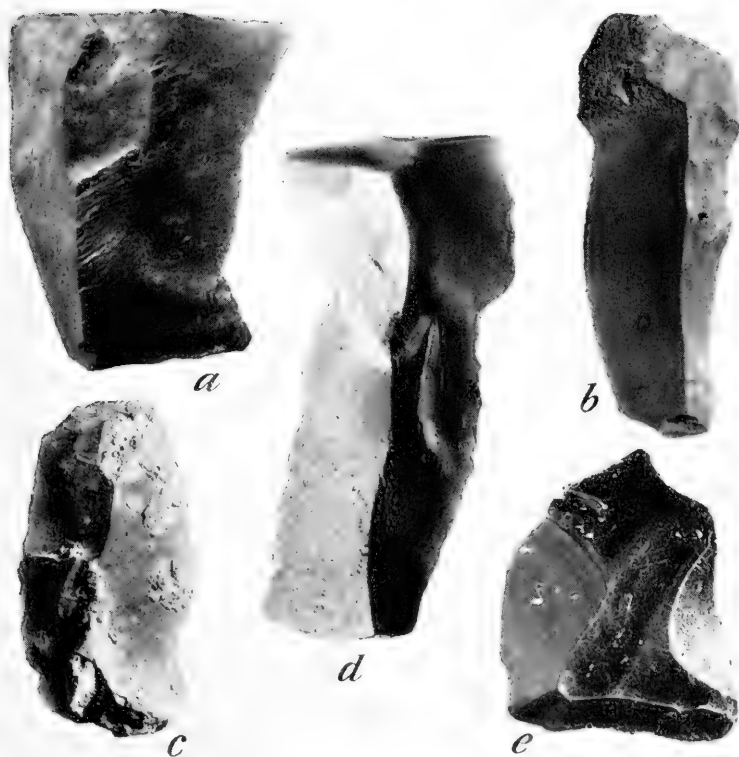FOLSOM BLADE EMBEDDED IN LOWER SURFACE OF TRAVERTINE CRUST
(Actual size.)

SNUB-NOSED SCRAPERS FROM FOLSOM LEVEL OF SANDIA CAVE

One, *d*, has additional feature of concave scraping surface in one side.
(Approximately actual size.)

1. Side Scrapers from Folsom Level, Sandia Cave
(Approximately actual size.)

2. Flake Knives from Folsom Level, Sandia Cave
(Approximately actual size.)

1, IVORY SHAFT WITH GROUND POINT FROM
SANDIA CAVE FOLSOM LAYER

(Approximately ¾ actual size.)
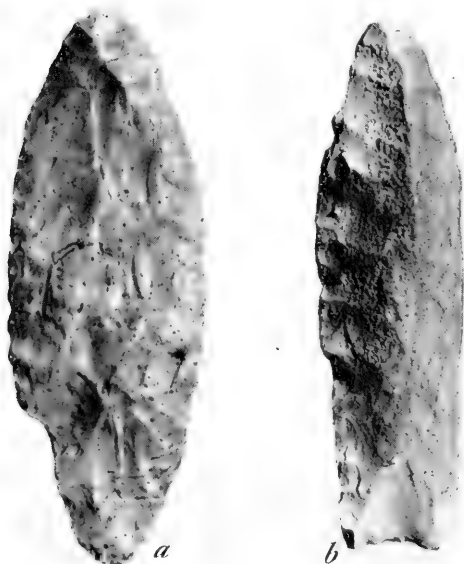
2. SANDIA POINTS

a, type 1; *b*, type 2. (Approximately actual size.)

SANDIA POINTS, TYPE 1
(Approximately actual size.)
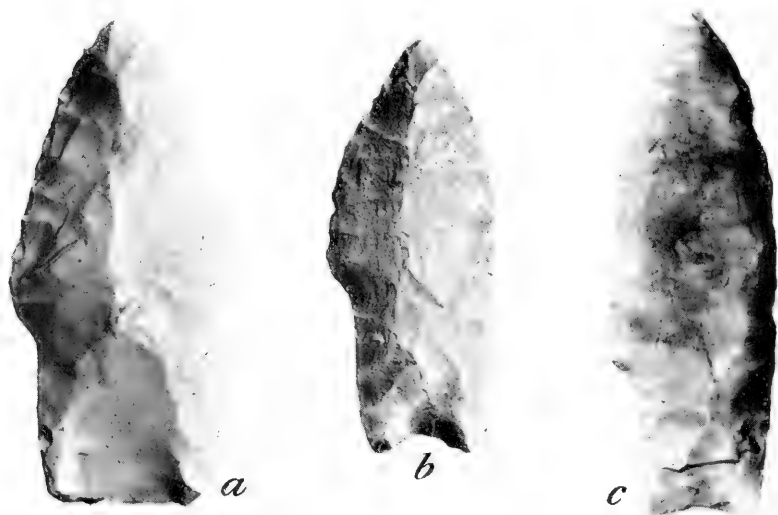
1. SANDIA POINTS, TYPE 2

(*a* and *b* slightly smaller than actual size; *c* approximately actual size.)
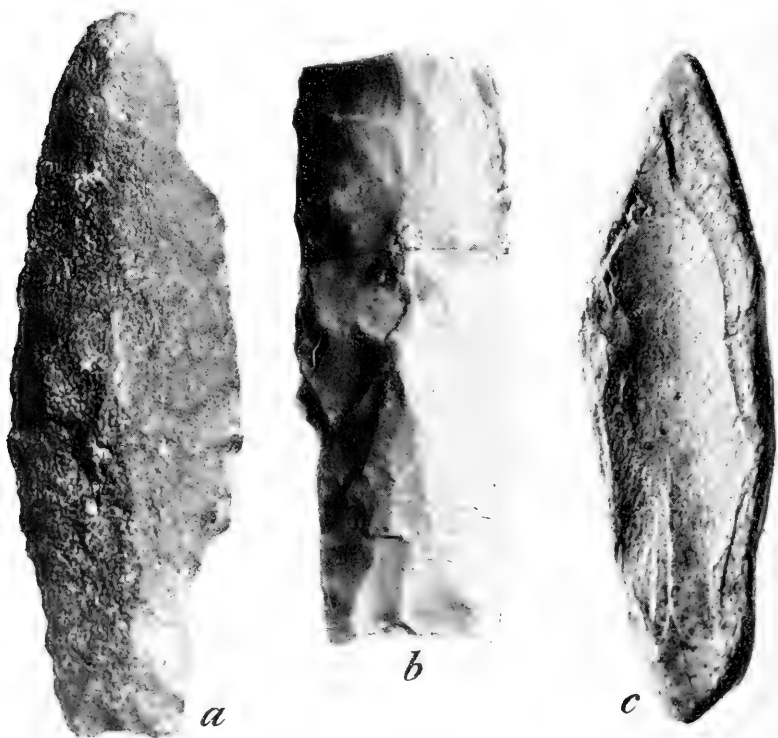
2. SANDIA POINTS, TYPE 2, AND BONE POINT

(*a* and *c* slightly enlarged; *b* approximately actual size.)

SANDIA POINT FRAGMENTS

a and *c* and crude point *b* from Sandia level.
(*a* and *c* approximately actual size; *b* approximately
¼ actual size.)
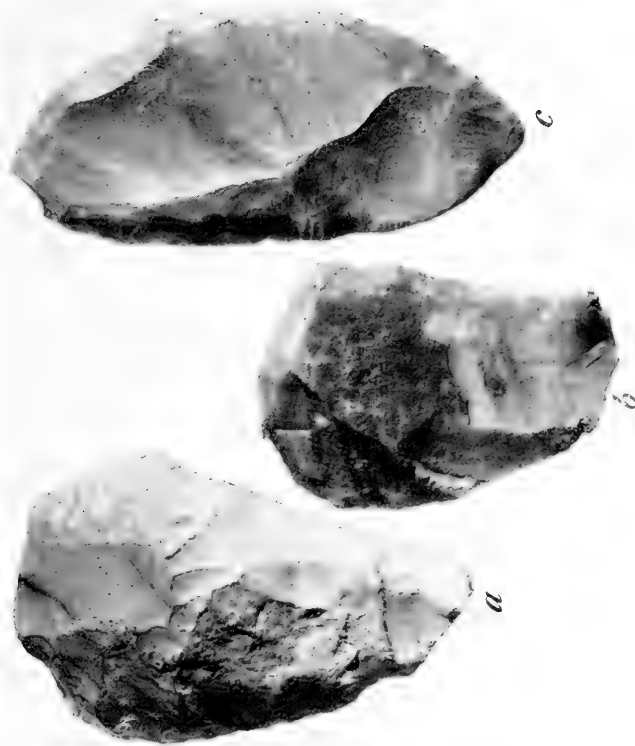
2. SCRAPERS FROM SANDIA LEVEL

a and *b*, snub-nosed scrapers; *c*, side scraper. (Approximately ¾ actual size.)
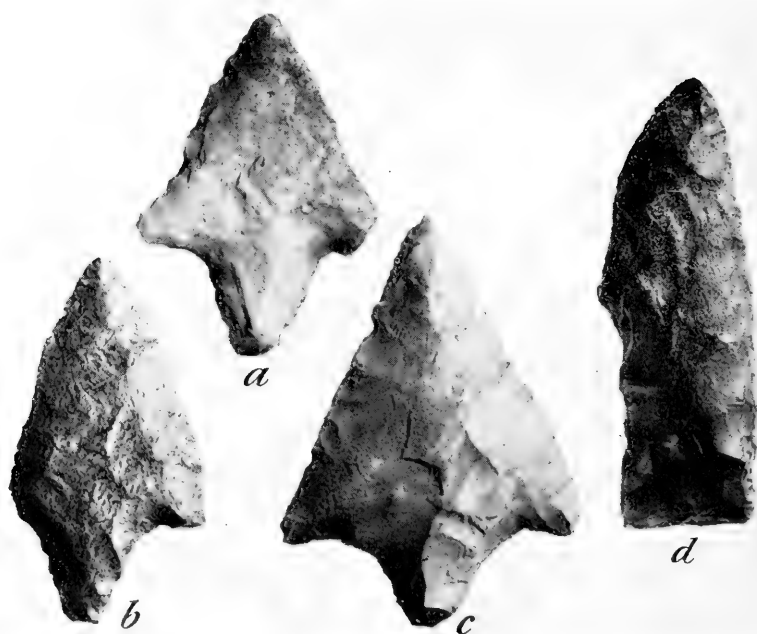
1. Points from Manzano Cave

a-c, Manzano points; *d*, Sandia point. (Approximately ⅚ actual size.)
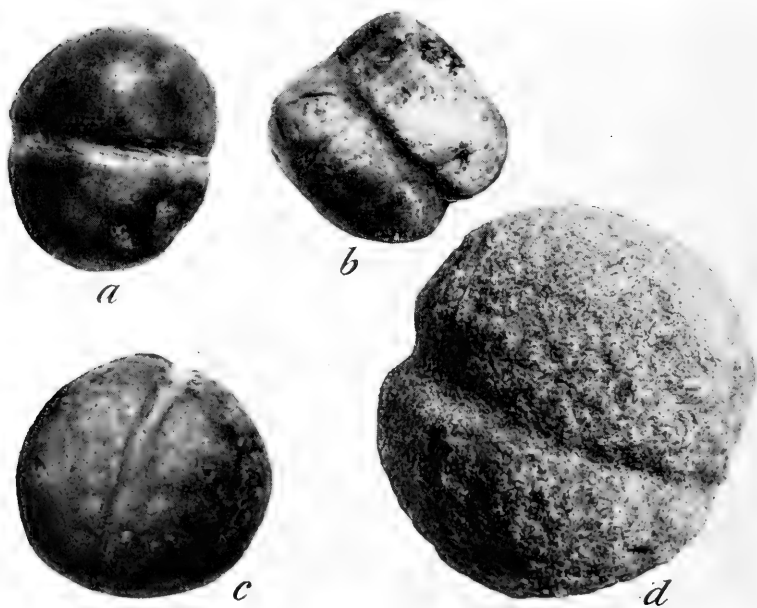
2. Bola Weights from Manzano Cave

a-c, limestone; *d*, granite. (Approximately ⅚ actual size.)

1. ROAD CUT IN SANDIA MOUNTAINS, FIR-SPRUCE ZONE, SHOWING SOLUTION-WIDENED JOINTS IN LIMESTONE CONTAINING LIMONITIC CLAY

2. ROAD CUT IN SANDIA MOUNTAINS, PINE ZONE, SHOWING DISINTEGRATED GRANITE WITH LIMONITIC STAIN
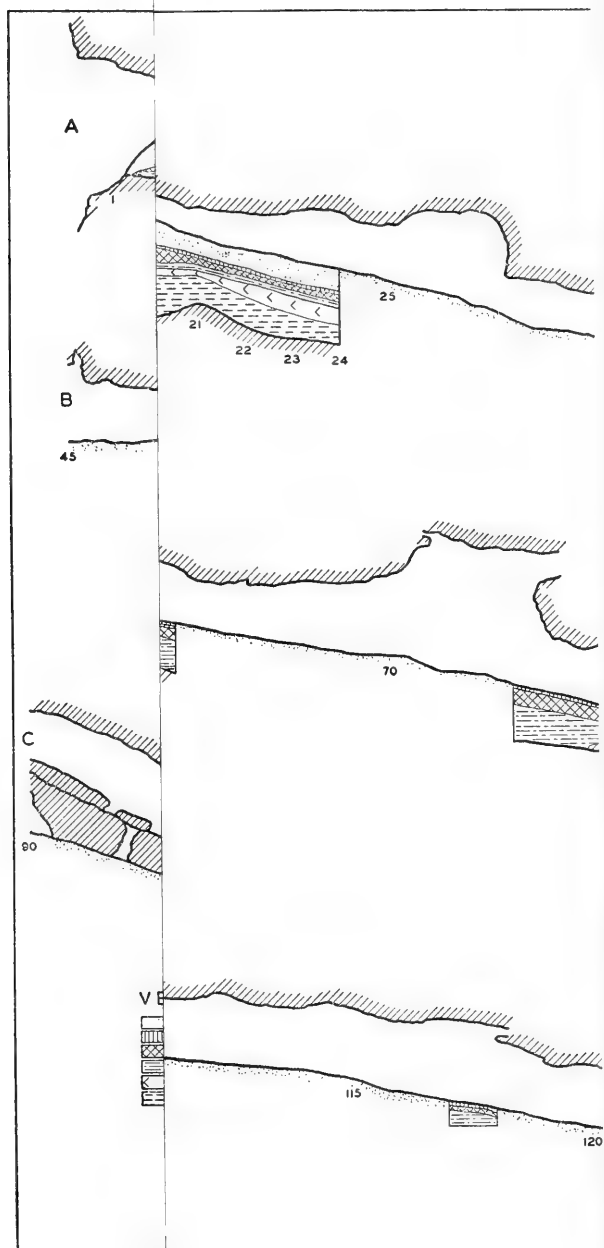
ave, vertical section showing stratigraphy.
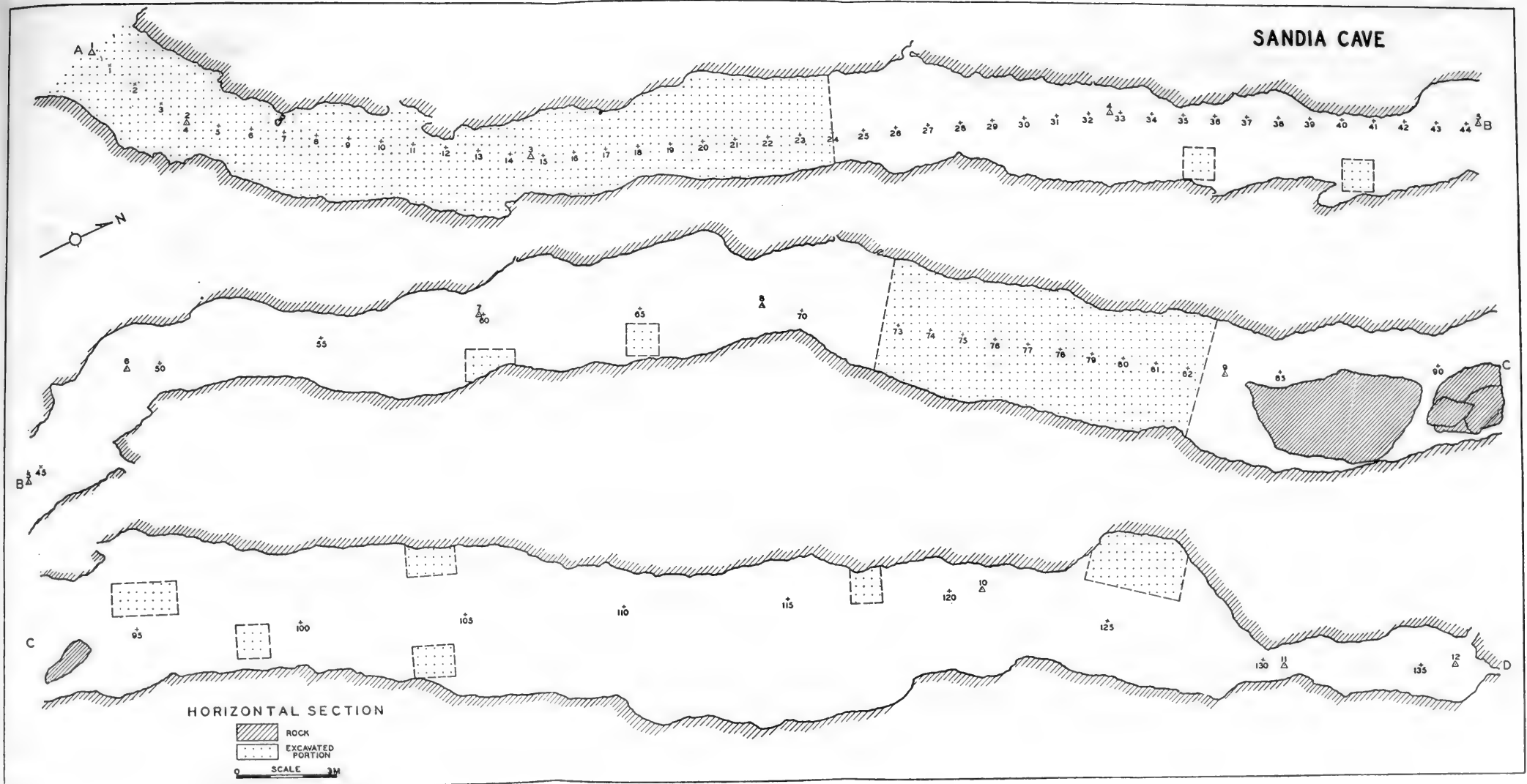
Fig. 2.—Sandia Cave, horizontal section.

SANDIA CAVE

STRATIGRAPHY

VERTICAL SECTION

	RECENT DEPOSIT
	CALCIUM CARBONATE CRUST
	FOLSOM DEPOSIT
	YELLOW OCHRE
	SANDIA DEPOSIT
	CLAY
	ROCK

SCALE
0   1   2   3M
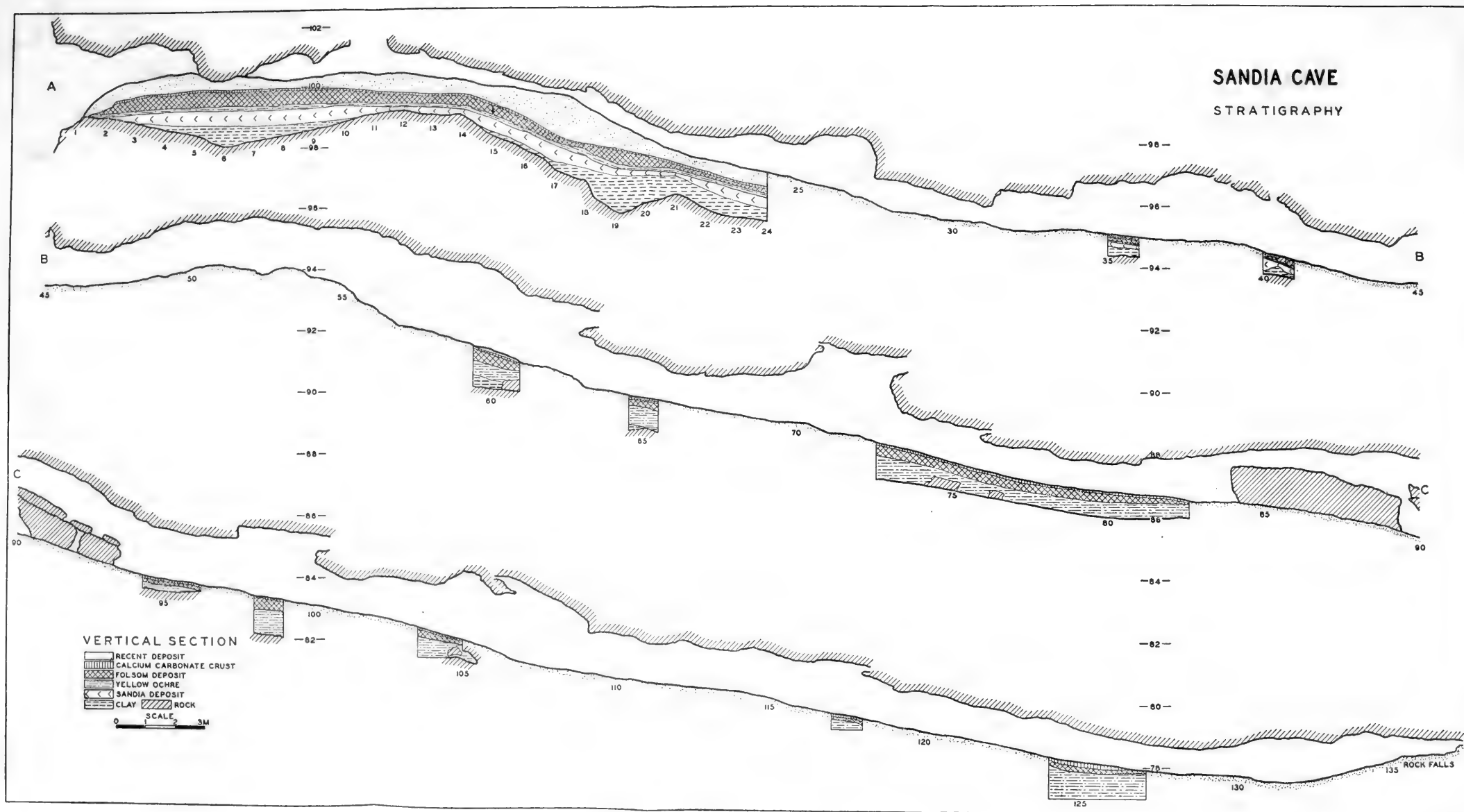
FIG. 3.—Sandia Cave, vertical section showing stratigraphy.

SANDIA CAVE

STRATIGRAPHY

٢

SANDIA CAVE

SOMEWHAT SCHEMATIC REPRESENTATION
OF DEPOSITS.
ALL ARTIFACTS LOCATED IN SITU
ARE SHOWN ON ONE PLANE.

RECENT DEPOSIT
CALCIUM CARBONATE CRUST
FOLSOM DEPOSIT
YELLOW OCHRE
SANDIA DEPOSIT
CHARCOAL
CLAY
ROCK
FOLSOM POINT
SANDIA POINT

SCALE
0   1   2   3M
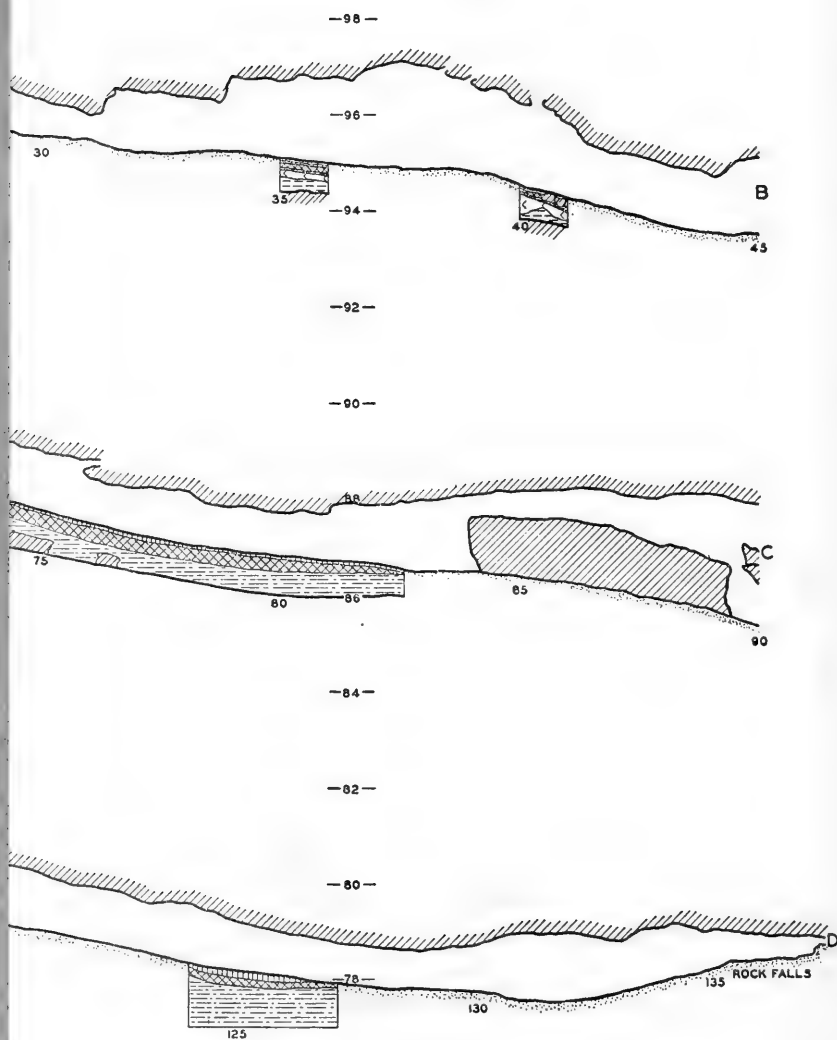
FIG. 4.—Sandia Cave, vertical section meters 1 to 24 showing location of artifacts and fire areas.
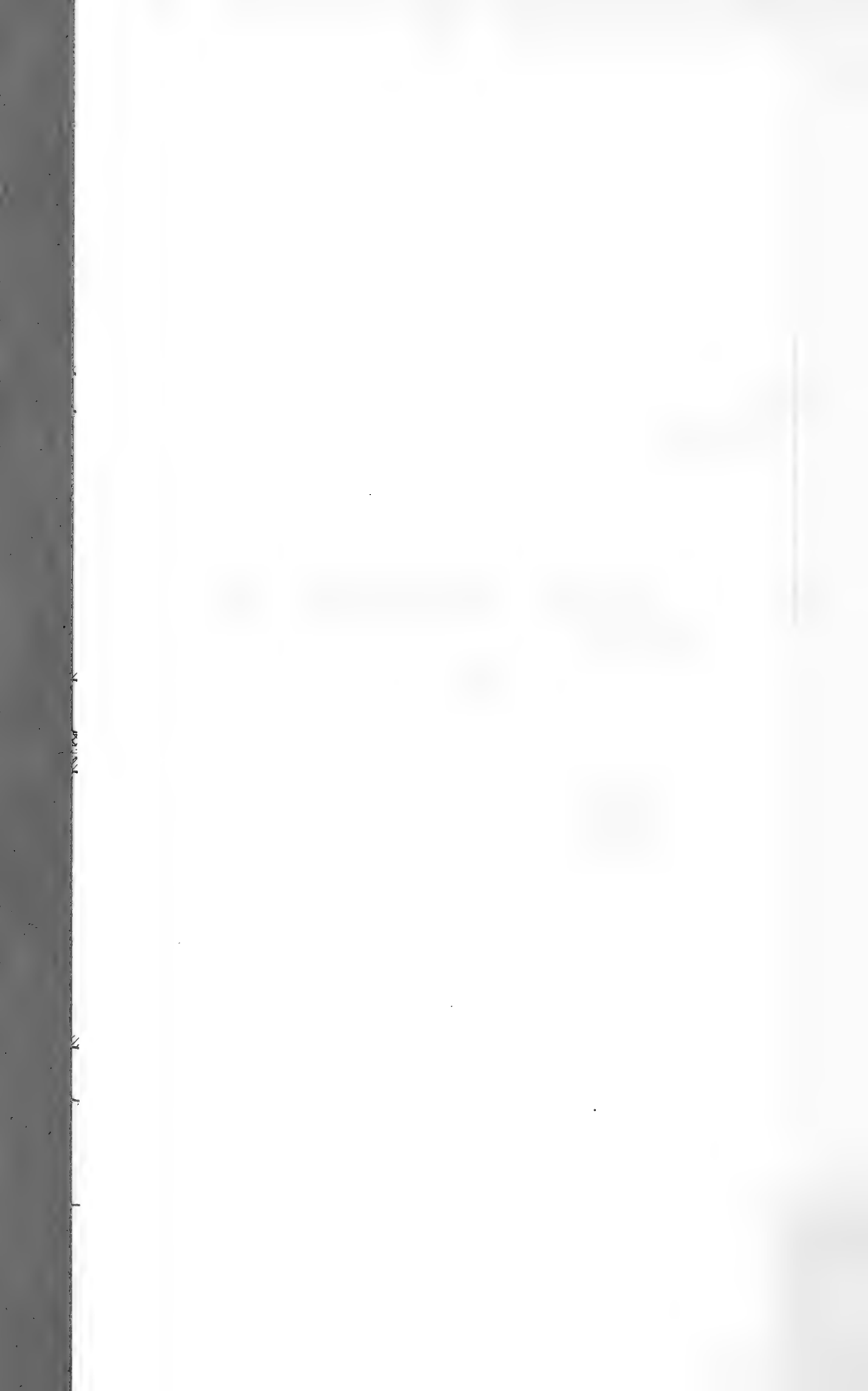
STRATIGRAPHIC SEQUENCE

The well-defined stratigraphy of Sandia Cave is one of its outstanding features. Figure 3 illustrates the precise nature of this stratigraphy and shows that it extends, with slight variations, throughout the cave. Stratigraphic sequences of this sort are of the utmost importance in determining relative chronology.

The deposits of Sandia Cave have no physical connection with any exterior deposits. For this reason, correlations with glacial phenomena and Pleistocene chronology known from open sites are somewhat difficult. Groupings of the strata within the cave necessarily are referable mainly to periods represented only by phenomena occurring within the cave. However, the problem of exterior factors such as stream erosion or accidental wash into or through the cave is practically eliminated. All objects and matter in the cave appear to have been deposited there originally. There was no deposition from the outside nor were original internal deposits redistributed by such factors as stream wash, solifluction, faulting, or other natural agencies of disturbance. These deposits, then, may be regarded as primary and may be judged in their relative positions. Such items as fire areas with undispersed lenses of charcoal reaffirm the undisturbed nature of the deposits. Naturally, a problem of this sort involves considerations different from those of a river-terrace or river-sediment site.

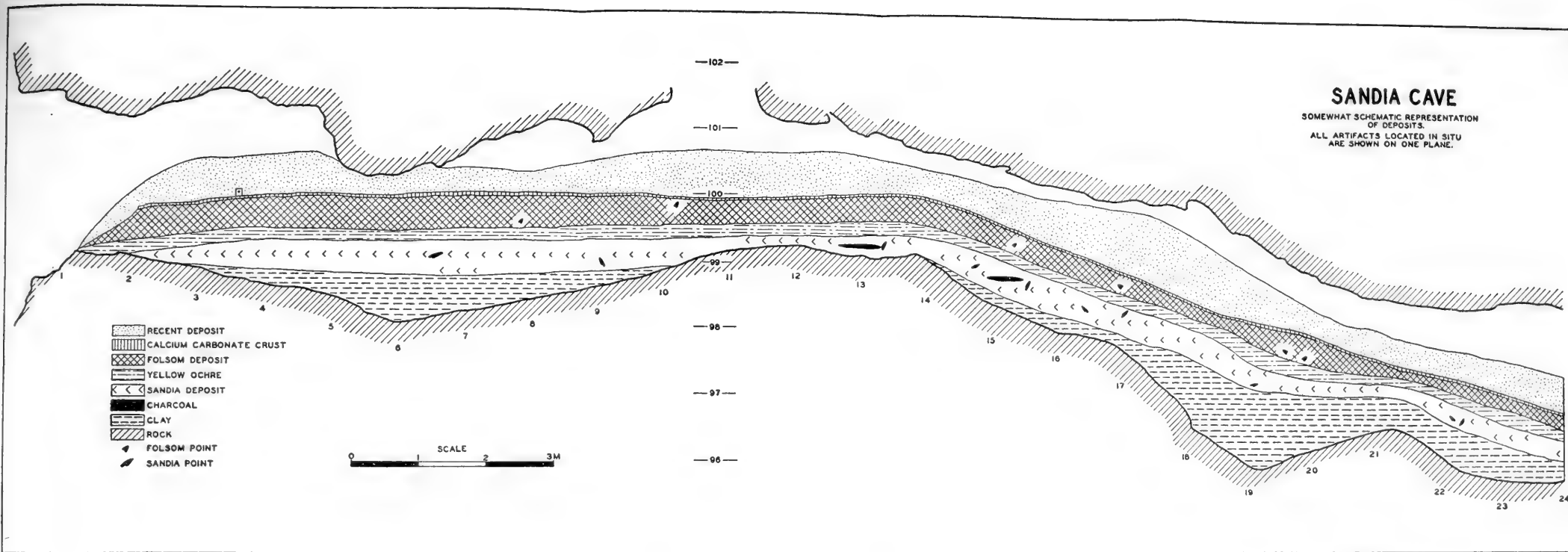The uppermost stratum, labeled "recent deposit" in figure 3, is for the most part wind-blown dust, bat guano, and pack-rat dung. The guano deposits occur in the greatest concentrations in the front portion of the cave, thinning toward the back, and disappearing altogether at about meter 70. Beyond this, only a very light covering of dust represents the uppermost stratum. The make-up of this layer is varied in places by the addition of small rocks and large slabs that dropped from the roof in recent times (fig. 6) and, at the very mouth of the cave, by a considerable quantity of wind-blown and pack-rat-deposited leaves and vegetable material. This top layer is entirely dry. Owing to this circumstance, and also to the fact that mammal forms found in it are for the most part living species, it has been labeled "recent."

In several places this recent accumulation extended to the roof. This completely blocked the passage and possibly accounts for the fact that there is almost no wind-blown material in the rear portions of the cave. At several places, in the first meters, where the accumulation reached the roof it even extended up into fissures where bats formerly roosted. From some lenticular stratification in this recent layer, it appears that there were intervals when the bats did not use the cave,

2

possibly when it was completely blocked and they could find no entrance.

Beneath this recent accumulation is the second definite stratum, a layer of calcium carbonate that extends in a continuous crust from the mouth to the extreme rear of the cave. This crust varies from a laminated lime formation a few centimeters thick to a crystalline cave-travertine layer as much as 30 centimeters thick. In some places sheets of stalagmitic material formed on the wall, and an occasional stalag-mite protrudes upward from the calcium carbonate crust into the recent layer mentioned previously. Throughout the cave the crust
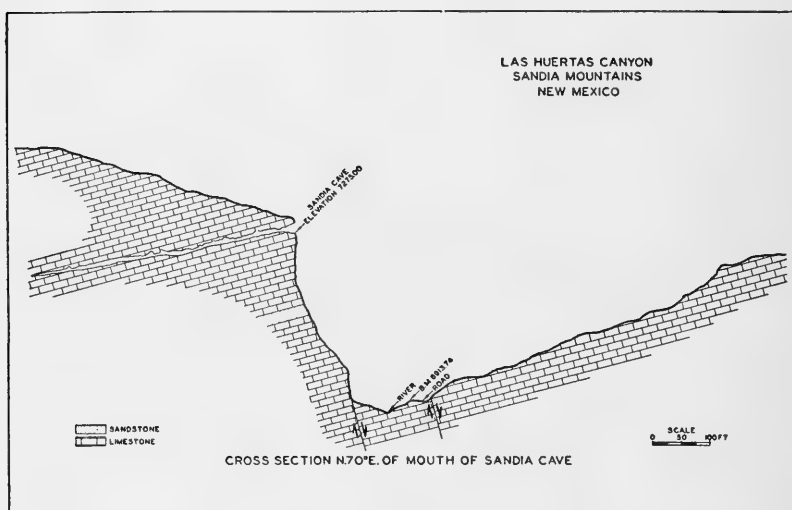
FIG. 5.—Las Huertas Canyon and Sandia Cave cross section.

was durable and practically impenetrable. In the front of the cave, near our meter 7, the Boy Scouts had dug through the crust to a limited extent in a search for treasure. The hardness of the lower layers, however, soon discouraged them. Near the rear of the cave, in two places at meter 75 and at meter 90, large sections of the roof had dropped subsequent to the formation of the calcium carbonate. These large pieces of rock broke completely through the crust and partially buried themselves in the debris below. At several places rocks of varying size from an earlier fall are incorporated in the crust. Most of them are completely encased in a layer of calcium carbonate.

Below the calcium carbonate capping is a stratum of cave debris. This has been termed the Folsom layer because typical Folsom arti-

facts are included in it (pl. 3, fig. 2). This Folsom stratum is composed of mixed material with a preponderance of stone and bone fragments. In addition, there are pieces of yellow ochre, crinoid stems, charcoal fragments, flint chips, and other cultural material. Orig-

CROSS SECTION
METER 10

RECENT DEPOSIT
CALCIUM CARBONATE CRUST
FOLSOM DEPOSIT
YELLOW OCHRE
SANDIA DEPOSIT
CLAY   ROCK

SCALE
0   ½M
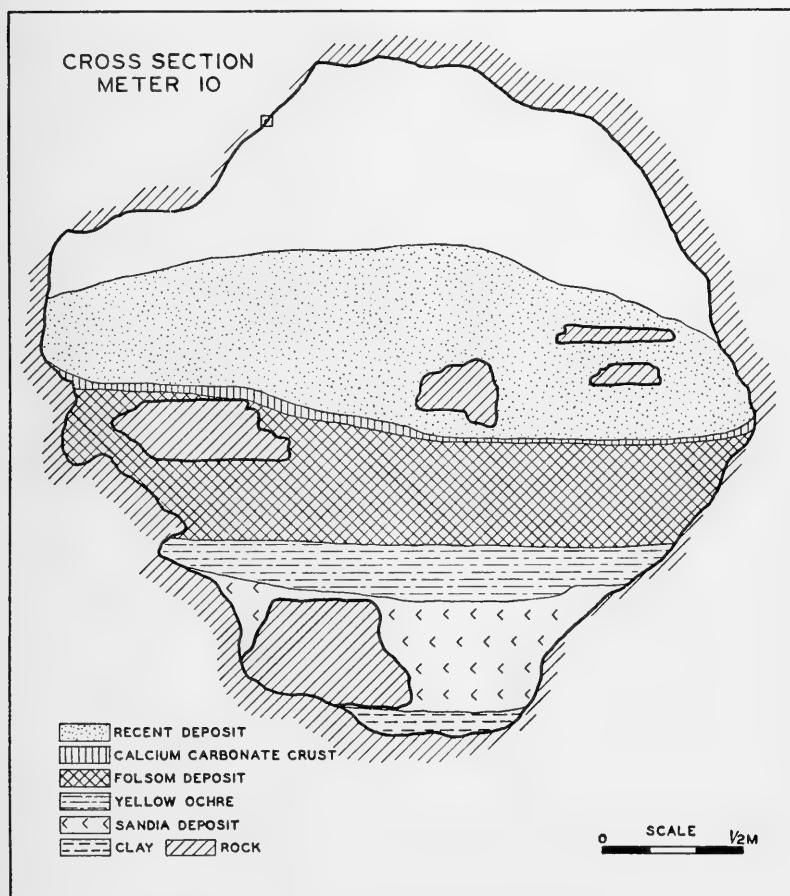
Fig. 6.—Cross section of Sandia Cave at meter 10.

inally, the Folsom layer apparently was a cave floor strewn with accumulated debris. Many of the fragments of animal bones represent the refuse of human occupation. Undoubtedly some of the bones also indicate the lairing of animals, either carnivores or cave-dwelling mammals in this same cavern. That the material was originally unconsolidated and loose seems evident from the size of the individual particles (see pl. 3, fig. 2) as well as from the fact that much of the

material has drifted down the slant of the passageway toward the back of the cave, possibly as a result of the continual passing of animals, or men, or both.

The Folsom layer is now, however, consolidated into a cave breccia. Much of the material has a hardness comparable to somewhat friable concrete. Many of the fragments of stone, artifacts, and even some of the bone pieces are covered with crystalline calcite. Waters highly charged with calcium carbonate from the stalagmitic crust above the Folsom layer have consolidated most of the material into a solid mass. That moisture destroyed much of the bone material seems evident. Most of the fragments were almost completely disintegrated as far as the bony structure was concerned, their presence being indicated only by cavities left in the breccia or by the arrangement of the calcite crystals. Evidently because of the porous nature of the Folsom deposit and the amount of moisture once present there, only a small number of the bone pieces were fossilized, and then usually with the addition of a heavy calcium crust deposited on their surfaces.

Although charcoal in very small fragments was relatively abundant in some parts of the Folsom stratum, it was nowhere concentrated in what might be construed as a fire area or hearth. It is significant that charcoal fragments extended to the very surface of the layer. A few pieces are embedded in the lower portion of the stalagmitic crust.

The Folsom stratum extends considerably farther back in the cave than would be expected. Even at meter 100 it is thick enough to be readily distinguishable. Artifacts and signs of occupation are, however, limited to the front portion. Only one large blade referable to the Folsom complex was found in the excavated section from meters 72 to 83. The whole Folsom layer naturally thins toward the back of the cave (fig. 3).

Beneath the Folsom stratum and in unconformable contact with it, is a layer of sterile yellow ochre, finely laminated and evidently waterlaid (see pl. 3, fig. 2). The laminations consist of differentiating streaks of light and dark ochre of a vivid yellow hue. Here and there lenses of the material were consolidated almost to the consistency of rock, apparently by a binding of calcite. All the ochre, in spite of its seemingly pure nature, is pervaded with calcium carbonate. Its mode of deposition, a purely geologic problem, is discussed by Professor Bryan in the appendix to this paper.

The top surface of the yellow ochre layer obviously suffered some erosion, apparently physical. In some sections a path or passageway,

worn by the movement of men or mammals back and forth through
the cave, may be noted on the top of the layer. Folsom debris lies
immediately above this unconformity, and the destruction of the top-
most layers of the yellow ochre is indubitably referable to Folsom
times.

The yellow ochre represents another wet period and is absolutely
sterile as far as bones, cultural material, or even rock fragments are
concerned. This sterility indicates a totally different set of conditions
from those surrounding the deposition of the layers both above and
below it.

The yellow ochre stratum, with the possible exception of the calcium
carbonate crust, is the most constant in the cave. The layer increases
in thickness toward the back of the cave (fig. 3), where, in certain
test pits, it achieves considerable depth. In some places in the rear
of the cave the yellow ochre extends to and rests on bedrock, to the
exclusion of other strata.

A sample of the yellow ochre was submitted to Joseph Berman,
Ceramic Laboratory, W. P. A. project 23676, University Museum,
Philadelphia, who, after exhaustive tests, made the following report
on it:

The sample of unconsolidated earth is a very fine ochre-brown clayey material
which sifts through such fine pores that it is difficult to find a container to keep
it intact. It feels only slightly gritty by touch and stains everything that contacts
it with its rusty iron color. Owing to the almost complete covering of all the
tiny mineral grains with a nearly opaque coat of iron oxide, there was much
initial difficulty in making a petrographic examination. Finally this coating was
removed with acids which also removed all of the small particles of calcite that
were present. The final product turned out to be a monomineralogic aggregate of
very tiny particles of quartz. They range in size from very fine silt to a maxi-
mum of 0.1 mm. diameter with the majority of the grains 0.01 mm. in diameter.
The mineralogical composition of this sample is quartz, many with euhedral
crystal outline, calcite (slightly dolomitic), and a great deal of hematite which
coats all of the mineral grains. The chemical analysis also shows that there is
some organic material present although it is of such small size and is so in-
crusted with iron oxide that identification is impossible. They definitely are not
diatoms nor spicules.

Conclusion.—From the petrographical and chemical evidence, it can be defi-
nitely stated that the deposit was a local one and that it was deposited during a
period of quiescence. If it were otherwise, there would certainly be a much
greater assortment of minerals present and any disturbance would not have
allowed the very fine material to be deposited in this cave.

Two theories may be advanced as to the mode and conditions of deposition.
First, the floor of the cave may have had a shallow layer of water continuously
covering it. The quartz particles present would then have been blown in as
fine dust particles and trapped there by the water. Second, the deposit is the
remains of dissolved limestone.

Evidence strongly favors the second theory. The absence of any alumina mineral argues against any but a local source. The fact that the cave slopes gently toward the rear "following the dip of the limestone strata" seems to preclude any shallow layer of water on the cave floor, and the presence of many small euhedral grains of quartz (as ordinarily occur in limestone) suggests very little transportation of the material. It is quite plausible that the deposit represents residual material remaining after the limestone has been removed in solution from the cave. All limestones have both iron oxide and small particles of quartz as impurities. Although these are present in small amounts, the dissolving away of calcium carbonate would tend to concentrate the quartz and iron oxide in the remaining material.

CHEMICAL ANALYSIS

SiO_2	12.78
Al_2O_3	Trace
Fe_2O_3	36.93
FeO	.28
MgO	2.10
CaO	22.00
Na_2	.48
K_2O	.14
H_2O	1.15
CO_2	13.60
TiO_2	.44
MnO	Faint trace
P_2O_5	.20
Loss on ignition (probably organic)	10.56
Total	100.66

Beneath the yellow ochre is another layer of cave debris. This represents the lowermost or earliest occupation of Sandia Cave. The material of this layer is more finely divided and less consolidated than that of the Folsom. It is composed of rock fragments, finely divided rock dust, bones, artifacts, charcoal, crinoid stems, and brownish-colored dirt, evidently wind-blown and mixed with vegetable and animal material. This stratum, because of the cultural items included, and its lower and distinct position in this cave, has been termed the Sandia level.

The top surface of this Sandia layer is not heavily consolidated and the yellow ochre rests directly upon it with no unconformity noted. Apparently, the yellow ochre was deposited directly on top of the cave debris, represented by the Sandia layer, with no disturbance other than the infiltration of the moisture carrying the ochre. There was, however, not sufficient calcium carbonate in the yellow ochre to consolidate completely the Sandia layer. Only in some isolated por-

tions, usually near the top, has any consolidation taken place. Even this has not formed a breccia, as in the Folsom stratum, but a friable and noncrystalline mass. The yellow ochre has, however, heavily impregnated the Sandia level with the typical yellow, finely divided dust.

That the Sandia stratum as a whole was moistened by the super-incumbent yellow ochre layer seems evident. Bones are poorly pre-served, and most of the identifications were made from teeth. Cultural evidence seems to indicate occupation of the cave to the very surface or topmost portion of the Sandia layer, where the yellow ochre lies upon it. Presumably, the Sandia layer represents a dry period in the cave's history, interrupted and made untenable by the succeeding wet period of the yellow ochre.

Portions of this Sandia layer were less disturbed or "scuffled" than the Folsom layer above. Two hearths, to be discussed subsequently, were found in position. Occasionally, bones, partially articulated, and cultural remains were discovered in situations where apparently they had been covered over with little or no disturbance.

The Sandia layer does not extend as far back into the cave as the Folsom. As figure 3 indicates, the Sandia stratum has almost feathered out at meter 40. As a matter of fact, as in the case of the Folsom occupation, it is remarkable that evidence is found so far back. No cultural indication in the Sandia layer occurred beyond meter 23.

Beneath the Sandia stratum, in some places, is another layer. This is the so-called clay layer, an accumulation of disintegrated limestone, almost white in color. Except for the inclusion of large numbers of crinoid stem segments, the material is sterile. The clay is homogeneous and compact in nature. It is laminated, evidently water-deposited, and contains a considerable amount of calcium carbonate. The top surface is pitted sporadically with small hollows apparently of human origin. In many places, the clay stratum completely fills a stream course or channel associated with the original formation of Sandia Cave.

The clay layer also feathers out toward the rear of the cave, and apparently does not extend beyond meter 70. However, it may occur sporadically farther back than this.

SIGNIFICANCE OF THE STRATIGRAPHY

Stratigraphic sequences involving the Folsom complex have long been sought. Data on post-Folsom sequences were expected when the cave investigations were started, and they would have added to

our knowledge of the cultural growth of the Paleo-Indian. But instead of another hunting culture to help fill the gap between Folsom man and the earliest Basket Maker remains in the Southwest, we have in Sandia Cave a complex earlier than the Folsom.

The priority of the lowermost, or Sandia, cave occupation is clear. How much time lapse occurred between the Sandia and Folsom levels is a matter of conjecture. Although there are cultural affinities between the two, over and above the fact that both represent a hunting economy, the interval between them was undoubtedly considerable. This seems indicated both by the evidence for an intervening wet period and by the thickness of the yellow ochre itself.

Since the initial use of the cave by man there has been a succession of dry periods interspersed and separated by wet ones. The yellow ochre layer, obviously water-laid, followed immediately after the Sandia occupation. The ensuing comparatively arid interval characterized by Folsom cultural material gave way to one with moisture sufficient to consolidate the deposit into a cave breccia and to form the overlying calcium carbonate or travertine crust that sealed in the lower strata and prevented the intrusion of later objects into earlier levels. The deposits accumulating during the subsequent dry period formed the stratum which is designated "recent." This succession of dry and wet periods has an important bearing on the chronological significance of the entire sequence in that it provides the basis for a geologic interpretation of the deposits and their correlation with Wisconsin glacial chronology. From the latter Professor Bryan concludes that the sterile ochre deposits correspond to the last ice advance of the Wisconsin and have a nominal date of 25,000± years. The Sandia group lived in the cave just before this nominal date and the Folsom just after it.

CULTURAL MATERIAL FROM THE CAVE

THE RECENT LAYER

Cultural material in this stratum was confined entirely to the very front of the cave, in spite of the fact that the level itself extended some 60 to 70 meters from the mouth. This cultural material in no wise represents a continuous or long occupation. It is obviously sporadic, judging both from the paucity of the remains and the time sequences involved.

Of the 11 potsherds from the very mouth of the cave, 2 were of Pueblo III date of the black-on-white type known as Santa Fe black-on-white (Mera, 1935, p. 16). The remaining potsherds were dis-

tributed evenly between Glaze I black-on-red, and Glaze IV.[4] Two sherds of the typical late Glaze corrugated utility ware were also present (see pl. 5, fig. 1). This whole sequence represents a late and intermittent occupation of the mouth of the cave, presumably on trips into the mountains by Indians from pueblos on the Rio Grande, in the vicinity of Bernalillo. It is difficult to understand why the cave should have been used at all, as its mouth was so inaccessible in recent times.

A crude metate of the type which is common in many cave shelters and temporary habitation sites in the vicinity was found just inside the mouth of the cave. It was evidently manufactured locally from a sandstone slab that approximated the shape of a metate. No mano accompanied it.

At the very top of the fill at the front of the cave was found a section from the base of a mule-deer antler cut with a steel edge. This piece may indicate any date from early Spanish times to the present.

Albuquerque Troop 13 of the Boy Scouts of America had in their possession (although they are now lost) several fragments of yucca cordage, feather cord cloth, and twilled sandals from the front portion of the cave. W. E. Bambrook, of Albuquerque, has a fragment of a coiled basket found there at the time the Boy Scouts made their original investigations.

Those portions of the recent deposit beyond the low portion of the roof of the cave near the entrance are devoid of cultural remains. Evidently at the time of the recent or Pueblo occupation accumulated material already reached the roof so as to impede further progress into the interior of the cave without some digging. Pack rats had carried sticks, yucca leaves, pinyon cones, and other typical debris into crevices and cracks of the roof at many places near the entrance. These animals are still very common in the cave, and maintained their residence during excavating operations. In the very rear portion of the cave, however, even the pack rats were absent. Pack-rat debris and bat guano are not found back of meter 70. Beyond this point the recent stratum is represented only by a thin layer of finely divided dust.

FOLSOM CULTURAL LAYER

The Folsom cave floor, as mentioned previously, rests upon the yellow ochre layer below and is capped by the travertine layer above. Although the Folsom stratum extends far back in the cave, to about

---

[4] Kidder and Shepard, 1936. See discussion on glazes in pt. 1, pp. 1-263.

meter 100, cultural material is not found equally over this whole extent. Flint flakes, artifacts, and charcoal are fairly evenly distributed from the front of the cave back to meters 20 or 21. Beyond this, cultural remains are widely scattered. One blade referable to the Folsom occupation was found at meter 75—the only artifact found in this whole excavated section (pl. 4, fig. 1).

The Folsom cave occupation is dated by the occurrence in this layer of typical or classic Folsom points. Two entire specimens (pl. 6, *a, b*) and two Folsom bases (pl. 6, *c, d*) were obtained from this layer of the cave. The illustrations show these to be typical Folsom points with all the essential features, outlines, and size of those from the type site at Folsom (Brown, 1929) or the extensive Folsom camp at Lindenmeier. These Folsom points from Sandia Cave, it is true, have the appearance of being somewhat poorly made. This, however, does not prevent them from being placed in a pure Folsom category, as some of those from the type site also have channel chips broken off short, or slightly askew (Roberts, 1935, pl. 5, *a, b*). Folsom points from Sandia Cave are sufficiently close to already known Folsom areas so that their occurrence here is not totally unexpected. Their situation in a cave is unusual but not unique (Howard, 1935, p. 69).

The occurrence of Folsom bases with the other portions missing is rather usual. As has been observed by Roberts (1935, p. 21), the occurrence of bases is to be expected, as many points were broken off in the field and the butts apparently carried back in the shaft to the camp—in this case the cave—to be replaced with new points.

The channel flakes, typical of Folsom sites where points were manufactured, are absent in Sandia Cave. This is the first of the evidence indicating that the cave was a hunting station only and not a permanent habitation site.

In addition to the typical Folsom points, projectile points of another type occurred with them. These would under certain circumstances be described as Yuma types (Wormington, 1939, pp. 22-26), although the term "Yuma" has been much misused. In this instance they are regarded as Folsom points lacking the channel on either face, but identical with them in all other features. As the term "Folsomoid" has likewise been much misused, these points are classed as Folsom of a still different form, or unfluted Folsom-shaped points, although admittedly this does not clear the confusion. Two of these were found in place in the matrix of the Folsom layer (pl. 5, fig. 2), and an additional entire specimen was recovered in the screen (pl. 6, *h*).

Sandia unfluted Folsom-shaped points are similar to and probably identical with some of the so-called Yuma points recovered at Clovis by Howard (1935, pl. 39). There, as in Sandia Cave, they occur with the typical Folsom forms. Similar points have been found in association with *Bison taylori* at a site near Tucumcari, N. Mex., investigated by the University of New Mexico. Roberts (1935, pls. 5, *i*, 6, *i*) also found similar points with the Folsom material at Lindenmeier. Apparently there is no time differentiation, but a cultural difference is implied by the fact that these Folsom-shaped points are absent at Folsom itself and uncommon at Lindenmeier.

These points have the even flaking considered so typical of the Yuma series. In outline, they are much like the Folsom, even to the indented base. The edges of the base are ground to a very noticeable degree for about one-third the distance up the blade. However, this is not only a Folsom as well as a Yuma feature, but also is present on other types found elsewhere. Inasmuch as this type of point occurs occasionally in association with typical Folsoms, yet is absent from other Folsom sites, it possibly should be regarded as indicative of a group of peoples contemporaneous with, but possibly distinct from, the Folsom.

A single point, also found in the Folsom layer, falls into a different category (pl. 6, *g*). It displays chipping suggestive of the Yuma and, like the points described, lacks the longitudinal grooves. It differs in outline, however, in that the blade narrows perceptibly toward the base. This lanceolate type of point is occasionally found in surface situations in the southern Plains area. It apparently was contemporaneous with the Folsom and may be merely a variation from the foregoing series, although it could be from another complex.

Artifacts of other categories were also present. Now considered an accompaniment, although not necessarily a criterion, of the Folsom complex are large blades such as those found at Lindenmeier and at Clovis (Roberts, 1935, pl. 15; 1936, pls. 5, 6; Howard, 1935, pl. 29). Two complete blades and three fragments were recovered from Sandia Cave. One of the blades, as mentioned previously, was the only artifact that occurred in the section excavated between meters 72-83. This blade was solidified in the typical cave breccia. The other whole example occurred near the top level of the Folsom layer and was cemented into the lower side of the travertine crust near meter 15 (pl. 7).

These blades show none of the delicate chipping or fluting of the Folsom or Folsom-shaped points. It has been well established at Lindenmeier (Roberts, 1935) that the Folsom points themselves form

only a small part of the Folsom complex, and that the tradition of fine workmanship as exemplified in the Folsom points does not necessarily carry over into other forms.

Gravers, considered as Folsom equipment although not exclusive to it, were also present. Five entire gravers of the usual type were found in the cave (pl. 6, *i, j, k, l, m*). These follow the outline of such artifacts occurring at Lindenmeier (Roberts, 1935, pl. 13) and were apparently used for the same purposes.[5]

Gravers have been divided by Wright (1940, pp. 31-48) into several types and classes on a basis of specimens found in Texas. Sandia Cave examples include both the sharp-beaked varieties and one example of a graver with a broader drill-like point (pl. 6, *n*). Both of these types occurred at Lindenmeier (Roberts, 1935, pl. 13; 1936, pl. 9). Although these gravers are apparently not exclusively Folsom in age or distribution, they may be taken with the accompanying artifacts as additional evidence that this particular level of Sandia Cave is Folsom in date.

Scrapers of three varieties also accompany the Folsom material of this level. Snub-nosed scrapers, side scrapers, and concave scrapers are all Folsom-complex adjuncts, although none of them may be considered distinctive or exclusive to Folsom areas or Folsom horizons. It has already been pointed out (Roberts, 1935, p. 23; Howard, 1935, pl. 31) that the snub-nosed scraper is practically timeless, and, for that matter, geographically useless as well. Snub-nosed scrapers from Plains sites are practically identical with Folsom specimens, in form as well as in their probable hafting and usage. Snub-nosed scrapers from the Danubian Neolithic[6] are indistinguishable from those of Sandia Cave.

Of the above three varieties of scraper forms, the snub-nosed is the most common in the Sandia Folsom deposits. Plate 8, *a, b, c, e, f,* and *g,* show these to be perfectly typical in all respects. Their chief distinction is to be noted in their size; the largest specimen from the Folsom level measures 4 centimeters in greatest dimension. As the scraper series from the Folsom deposits of Sandia Cave is comparatively small, it seems valueless to go into subtypes paralleling those of Roberts (1935, p. 23), although most of these subtypes seem to be present in the Sandia collection.

---

[5] Roberts (1936, p. 26) suggests that these gravers might have been used for tattooing as well as for engraving bone.

[6] Specimens in the collection of the Museum of Anthropology, University of New Mexico.

Four side scrapers make up the total of that type of implement from these deposits. They exhibit considerable range in size and degree of finish. All are distinguished by being formed from a flake, one or both edges of which were carefully dressed by rechipping. In general, the convex surface of these implements was chipped so that the concave edge could be used (p. 9, fig. 1).

A single scraper in the collection differs radically from the others (pl. 8, *d*). This might be termed an end scraper but is perhaps better described as a scraper with a concave cutting edge. This is very similar to one described from the Lindenmeier site (Roberts, 1936, fig. 3, *b*). It apparently combines ordinary scraping functions with shaft smoothing.

In addition to the above more or less definitely formed siliceous artifacts, there are also in the collection heterogeneous flakes of indefinite shapes. Many of these would serve well as knives and a few approach vaguely flake-knife forms of Neolithic horizons (pl. 9, fig 2). None of the latter are, however, of definite enough form to be included in a regular flake and core classification. A few flakes of irregular outline were apparently chosen for their sharp cutting edges. Flake knives of similar form are also Folsom accompaniments as at Lindenmeier (Roberts, 1935, pl. 14, *a, b, c, d, e;* 1936, pl. 11). Others are obviously merely waste material. It is interesting to note that such waste material is remarkably scarce in the cave, and the site may be in no wise regarded as a place where flint was worked extensively.

Also in the Folsom cave debris occurred occasional pieces of worked bone. These may have been at one time much more common than their sporadic occurrence in the collection would seem to indicate, as bone preservation in the Folsom level was not ideal. The largest and most interesting piece is a splinter apparently of ivory(?) (pl. 10, fig. 1). This has a generally elongated shape but flattish cross section. It was sharpened to a spatulalike point at one end by means of abrasion.

Two other bone splinters in the Folsom-stratum collection show slight signs of working along one edge but have no distinguishable form. This working may be secondary as a result of using the splinters for scraping purposes.

Also in the category of cultural material from the Folsom floor are numerous fragments of charcoal. For the most part these fragments were extremely small and were well mixed with the other debris. If any definite fire areas had existed in the Folsom level, they had been obliterated by the passage of men and beasts, by movements that would disturb such areas and tend to pulverize and mix the charcoal

with other materials. Fragments of such charcoal occurred from the bottom of the Folsom level, where they actually were embedded in the yellow ochre, to the topmost portion of the deposit where some fragments were encased in the stalagmitic crust.

Cultural Material from the Sandia Layer

As the Sandia layer was less firmly consolidated than the Folsom above, its excavation was considerably facilitated and more artifacts were actually found in place in the cave, rather than in lumps of the breccia after they were moved to the laboratory, as was often the case with the Folsom material. Thus an exact check could be kept on the occurrence of the Sandia objects, especially as the accumulation of that stratum seems to have continued over a considerable period of time.

The projectile points from the Sandia deposit are its most distinctive cultural feature. Nineteen whole or broken points were recovered from this layer. They tend to separate into two main categories.

In the lowest levels occurred a type that may be described as lanceolate or rounded in general outline. The base has a side shoulder or notch on one side, in what may be accurately described as a Solutrean manner. These points may be matched detail for detail in Solutrean collections (MacCurdy, 1937). This similarity to Solutrean material does not necessarily imply connection or contemporaneity with it, although the resemblance is remarkable.

The chipping on the Sandia points from the lowest levels is good but not fine. It displays a chipping tradition differing radically from the careful retouch of the Folsom points in the level above. There is no suggestion of basal thinning or facial channels in these lowermost Sandia examples, although the edges of the base are ground. This form may be tentatively identified as Sandia type 1 (pl. 10, fig. 2, *a;* pl. 11).

At several places in the Sandia level as a whole, there are evidences, although not very clear ones, that the Sandia deposits represent a dual epoch. In the vicinity of meter 17 occur thin and sporadic sterile layers, as though the cave had been unoccupied for a short time. Above and below this somewhat uncertain separation, the projectile points of the Sandia show some differences. Sandia points from the upper levels of the stratum may be described as elongated, with parallel sides and straight or slightly indented bases. In cross section, this tends to be diamond-shaped rather than lenticular. Plate 10, figure 2, *b,* and plate 12, figure 1 and figure 2, *a, b,* show that this type also has the

typical Sandia side notch. These points likewise may have parallels in Solutrean collections, and conform closely to the outlines of the famous late Solutrean points à cran (MacCurdy, 1932, fig. 22). These points, which may be designated as Sandia type 2, show some differences in chipping from the earlier ones. There is a tendency to thin the base, although the removal of such basal chips may not be considered in any sense as comparable to actual fluting. The chipping on the body of the blade is slightly suggestive of certain so-called Yuma types, as is the flattened, diamond-shaped cross section. Dr. Roberts, in a personal communication, has suggested that these points may be proto-Yuma forms. Their position below the Folsom in Sandia Cave possibly, although not necessarily, adds weight to such a supposition.

The side-notched form of Sandia type 2 connects it with type 1. Indeed, it is difficult to decide to which type certain specimens belong. Hence the present subtyping may not have validity under all conditions. Prevalence of the side shoulder or side notch establishes that feature as a distinguishing characteristic and the distinctness of both the Sandia types from the Folsom is a salient factor.

Certain of the points from the Sandia layer (pl. 13, fig. 1, b, c) are so nondescript in shape that they fit neither type. They may be regarded merely as crudities or aberrant specimens.

Snub-nosed scrapers also appeared in the Sandia level. Three of these were recovered (pl. 13, fig. 2, a, b). The main characteristic distinguishing these from similar scrapers of the Folsom stratum is size. Snub-nosed scrapers of Sandia times range from 7 to 10 centimeters in greatest dimensions, as contrasted with the very small examples from the layer above. Also, the Sandia snub-nosed scrapers are not so finely chipped or finished as those of the Folsom.

The snub-nosed scraper in the Sandia level adds another and earlier chapter to the long and varied history of this interesting implement. In spite of the comparative crudity and size of the Sandia examples, there is no doubt that they were used and possibly hafted much as were those of later times, such as the well-known Plains scrapers of this class. Their presence and consequent usage seems to indicate work on the skins of animals, as was apparently the case in Folsom and also later times. It is interesting to note that the snub-nosed scraper now has a chronological distribution as long as, or longer than, any other known type of artifact not excluding the arrowhead. Its geographical distribution is equally impressive. The snub-nosed scraper is common to both the Old and New Worlds. Exactly parallel forms occur in the European Neolithic, Siberian and

Chinese Neolithic, and in the New World. Bird (1937) discovered snub-nosed scrapers in very early levels in cave sites in southern Chile and Tierra del Fuego. Here he noted (1937, p. 36) a scraper sequence in which the small or "thumb-nail" scrapers of the snub-nosed variety appeared suddenly in an upper level.

There were numerous rough flakes in the Sandia level and although most of them may not be regarded as actual implements, a number were undoubtedly used for cutting purposes. Their natural sharp edges would have functioned well in such a capacity. Apparently this is but another indication that chipping techniques of the Sandia level were not advanced as far as those of the Folsom. Folsom blades or flake knives were struck off with some certainty as to the result of the final outline, the desirable form being an elongated shape with roughly parallel cutting edges. In the Sandia stratum nothing of the sort occurs.

Only one side scraper occurred in the Sandia level. This is made in the usual manner from a large flake and is chipped on both edges (see pl. 13, fig. 2, c). It differs in no radical way from similar scrapers of the Folsom or, for that matter, of many other later cultures. These side scrapers, both in the Sandia and the Folsom level, vary widely as to exact outline and degree of finish. Apparently, they were made on the spur of the moment, and their degree of refinement varied with the specific use for which they were intended.

Perhaps the most interesting variation of the Sandia level is the occurrence of two items of worked bone. They are points of bone seemingly similar in purpose to the projectile points of stone previously described. One of them (pl. 12, fig. 2, c) is especially well worked and approaches the general outlines of a Sandia point. A slight side shoulder or notch is present, and the base is rounded after the manner of a type 1 Sandia point. The other point, although fragmentary and in a poor state of preservation, is apparently similar, both in outline and in size. Both were made from a fragment of the shaft of a long bone from a medium-sized animal. From the general contours and curvature of the best-preserved point, this appears to be one of the long bones of *Camelops*.

Bone points are not out of place in the Sandia collection, and their occurrence in this instance occasions no surprise. Primitive hunters from Mousterian times on were accustomed to use either artificially shaped or accidentally splintered bones of various kinds. Roberts (1936, pl. 9, e; also personal communication) in the last seasons at Lindenmeier especially, has recovered an impressive col-

lection of bone implements in connection with the Folsom industries there. The supposition is that both the Sandia and Folsom inhabitants of Sandia Cave utilized bone more extensively than the mediocre preservation in the cave would seem to indicate.

Two definite hearths, or fire areas, occurred in the Sandia level, although flecks of charcoal were fairly abundant throughout. Figure 4 shows both of these to be well within the mouth of the cave, although, as Professor Bryan suggests, there may well have been more in the portions of the cave now eroded away. The first hearth encountered, that at meter 13 (meter 7 according to the survey of the first year of excavation), was a large area of finely divided charred material measuring some 45 centimeters in greatest width by 30 centimeters in depth, and extending in small pockets or lenses down to and partially into the surface of the white clay layer below. The material itself was too finely divided to be identified specifically, but it represented oak and some species of resinous trees. Around the edge of this fire area was a partially enclosing circle of rounded boulders, averaging 10 centimeters in diameter. These rounded boulders, although also of limestone, apparently were brought from the creek in the bottom of the canyon and were in marked contrast to the angular fragments of stone usual in the cave debris. These small boulders roughly outlined the charcoal area and may have been used to keep the ashes from spreading or to act as supports or partial fire dogs for sticks, for roasting pieces of meat, or the like.

Just outside the fire pit and actually touching one of the boulders was a Sandia point (pl. 10, fig. 2, a). This point is of the rounded variety and is good evidence for assigning the hearth to the earlier phase of Sandia occupation.

The other hearth, at meter 15 (figs. 4, 7) was unembellished by any boulder ring. It contained a concentrated quantity of charcoal in finely powdered form. Mixed with the charcoal were charred fragments of bone and calcined remnants of other bone pieces cemented into a mass by calcium-charged waters seeping down from above.

A possible explanation for the preservation of hearths in the Sandia level, in contrast to their absence from the Folsom above, is that they probably were covered over before they could be dissipated by the passage of men and animals back and forth through the cave. Undoubtedly, other fire areas that existed in the Sandia level were so obliterated, as were similar ones in the Folsom horizon.

3

Materials Utilized in Cultural Objects

Flinty materials used in the manufacture of cultural objects in some cases give definite evidence as to origin. The sources of various varieties of flints, chalcedonies, cherts, and the like, are not as yet
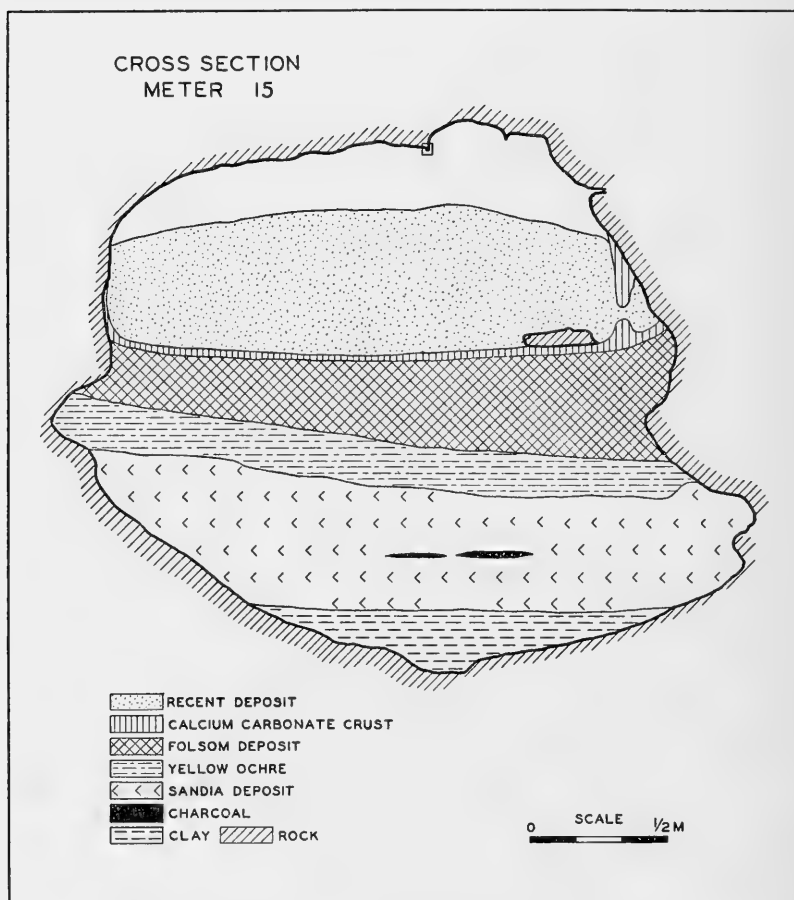
Fig. 7.—Cross section of Sandia Cave at meter 15.

well known in the Southwest, although studies of this nature are progressing at the present time (H. Holmes Ellis, 1940). The prehistoric quarries near Amarillo, Tex., are well known, and material from them can be identified, at least in most cases. Of more immediate moment are the chalcedony pits of the Pedernal region of New Mexico, especially as these give evidence of considerable antiquity (Bryan, 1939). Certain varieties of obsidian, that from the

Jemez Mountain area for example, are distinctive. Many and varying types of materials from quartzites to fine chalcedonies were used in the manufacture of tools in eastern and southeastern New Mexico in prehistoric times. Sources for most of these can only be suggested at the present writing, although even a rudimentary survey indicates that objects of similar materials tend to classify themselves into regions and areas.

Materials utilized in the manufacture of the artifacts from Sandia Cave, in both the Folsom and Sandia levels, are varied, although the general observation may be made that many are local or from the general Sandia-Manzano region. Quartzites are notably scarce in the collections. This is a distinctly negative feature by reason of the fact that quartzite scrapers in quantity—in some cases actual points— are present on the classic Folsom sites in eastern New Mexico and even on the Folsom site in the Estancia Valley near Stanley, only 20 miles east of Sandia Cave.

In the recent level of the cave, the few chips and artifacts present were all of the multihued and usually translucent chalcedony of the Pedernal variety (H. Holmes Ellis, 1940). This chalcedony, or cherty material, occurs commonly in the river terrace gravels along the Rio Grande at no great distance from Sandia Cave. The material on the Rio Grande terraces is usually in boulder form and is generally unsuitable for implement manufacture because of numerous fracture and cleavage planes as well as flaws. It was satisfactory, apparently, for such small items as rough scrapers, irregular flake knives, and the like.

The Folsom level of Sandia Cave presents a more varied list of materials. Pedernal chalcedony is present in the form of chips, flakes, and snub-nosed scrapers. The Folsom points themselves are of materials approaching the chalcedony classification but apparently of a different source. The unfluted point embedded in matrix shown in plate 5, figure 2, is of white chalcedony similar to material from the region around Clovis, N. Mex., although the exact source is unknown. The Folsom point shown in plate 6, *b,* is of brownish agate chalcedony not uncommon in southeastern New Mexico. The Folsom base, *d,* is of mottled purplish chert, a material occurring in the Texas Panhandle.

Of utmost importance is the observation that a considerable portion of the Folsom artifacts from the cave were apparently made from local materials. Cherty concretions in the Magdalena limestone of this region and in the very walls of the cave itself are of such a consistency that workable nodules may be found in some portions.

A fairly satisfactory mottled gray chert is rather common. Chert of a buff cast with a slightly gritty surface also occurs in the limestone and is undoubtedly the material represented in the Folsom point in plate 6, *a*. A number of the scrapers are also made from local materials.

The Sandia stratum is even more local, as far as material aspects are concerned. The Sandia points in plate 10, figure 2, *b,* and plate 13, figure 1, *b,* are made from cherty concretions of local origin. Chalcedony is not common in this level, although fragments occur. There are two fragments from points made from andesite.

Certain items in the Sandia collection appear foreign to this area. One Sandia point of a smooth-grained brown chert is unparalleled by any fragments of material from the Sandia-Manzano area.

The lack of complete information on source distributions of the flinty materials prevents the drawing of definite conclusions on the origins of Sandia objects. However, the fact that local materials were used to such a large extent is significant as evidence that there was more than a merely fortuitous occupation of the area by a transitory group.

Correlation of the Sandia Cultural Deposits

Certain definite conclusions may be drawn from the cultural material from Sandia Cave as well as from other less explored sites in the region. The significance of most of the material is self evident. Much of it has been paralleled in other places and can be regarded merely as additional supporting evidence. Certain factors, though, do contribute further information on the question of the Paleo-Indian.

The few potsherds found in the layer of recent material indicate definite affiliation with the Pueblos of the Rio Grande area. Glaze wares of this sort may be duplicated at Paako, Sandia, Kuaua, or Puarai. These sherds may be the results of sporadic excursions into the mountains by inhabitants of these late pueblos. It has been suggested that this late Glaze evidence may be correlated with the period of the Pueblo Revolt in 1680, when large portions of the pueblo population fled to refugee areas to escape the vengeance of the returning Spaniards. Even though some of the glazes are too early to fit into such a historical theory, there is a remarkable chronological parallelism in the sherd evidence of the many caves and rock shelters of the whole Sandia region. It seems that they were all used at about this time. Pottery is not usually carried on hunting trips.

Correlations of the Folsom layer with other sites of similar culture may be summed up as presenting three alternatives. The Folsom level of the Sandia Cave is:

1. Contemporaneous with previously known Folsom.
2. Peripheral to Folsom.
3. Later than classic Folsom.

Of these three alternatives, which of course do not exhaust the possibilities, the first seems to be the most logical. There is no reason to doubt that this level of the cave was contemporaneous with other Folsom centers, such as the type site at Folsom, N. Mex., Clovis, N. Mex., or Lindenmeier, Colo. Although not in as great a quantity, the list of implements accompanying the Folsom is typical in all respects and undiluted by any extraneous element of later date. Furthermore, the sealed-in character of the Folsom precluded the possibility of disturbance, a circumstance not present in most open sites.

The last two possibilities may be grouped together. Sandia Cave may be regarded as somewhat peripheral in relation to general Folsom distribution in spite of its nearness to the Estancia Valley, which was evidently good Folsom territory. In such a peripheral status, it may be argued that the Folsom of Sandia Cave would therefore be of later date. Such a contention is supported by the fact that the Folsom points of the cave are somewhat crudely made. Facial channels may be complete on one side and only partial on the other as a result of the too abrupt breaking off of the channel flakes. Materials chosen for some of the points are comparatively poor. Even all this evidence, however, does not sum up to a late date for the Sandia Folsom.

The faunal assemblage associated with the Folsom level of the cave is in every respect late Pleistocene in character. Only one animal, the sloth, might be considered as indicating a later date, but even *Nothrotherium* has been found in typical Pleistocene associations.

Sandia material, from the lower levels of the cave, is more difficult of correlation because of lack of parallels. The earlier status of this culture is evident. Its geographical extent is not nearly so plain. Since the original discovery of the Sandia level, the University of New Mexico has been at some pains, through its various agencies, to gather additional Sandia material. This has been extraordinarily scarce and hard to find. Some indications are, however, coming to the fore. Sandia points occur sporadically from southeastern Colorado to central Texas. The bulk of the Sandia points located so far come from the southern region of the Plains, centering about south-

eastern New Mexico and western Texas. Points of the earlier Sandia type, according to present information, seem to have the widest distribution. Some of these (the lanceolate or type 1) occur sporadically throughout the Mississippi Valley and along the eastern seaboard. The problem in this instance is remarkably parallel to that of the relationship of the classic Folsom point to the "Folsomoid" types found over such a wide area in North America.

Type 2 Sandia points or "proto-Yuma" types are apparently of more limited distribution, being confined entirely to southeastern New Mexico and adjacent portions of Texas. This distribution, of course, may be widened with additional information.

One fact becomes evident as the cultural material of both the Sandia and Folsom layers is viewed. There is no doubt that the cave was occupied only intermittently throughout both of these periods. There is no evidence of long habitation or of use of the cave as a workshop or chipping ground. Unfortunately also, a lamentable feature is that the cave was never used for burial. The Sandia Cave may be regarded, then, as a hunting station utilized successively by several cultures.

PALEONTOLOGIC IDENTIFICATIONS

Faunal material was not abundant in the cave in either the Sandia or Folsom levels, as preservation was generally poor, owing to the various wet periods in the history of the cave. Although fragments were generally small, and in many cases badly eroded, their aggregate number is large. A satisfying portion of the paleontologic collection consisted of teeth, which are generally very good for identification purposes. In certain areas of the various strata, owing to vagaries of the percolating, calcium-charged waters, bone preservation was better than the average. In such places "nests" of bone material were encountered, either highly fossilized or otherwise preserved, in some cases covered entirely with a coating of calcite crystals. Articulated, or semiarticulated limbs of *Camelops* and *Equus* were found under these circumstances. Such a large percentage of the bones, however, were represented only by splinters and fragments that artificial breakage to extract the marrow must be the explanation. It is somewhat more difficult to explain the presence in the cave of large numbers of teeth, including those of *Elephas* and *Mastodon*. It seems illogical that the bulky heads of such animals would have been carried into the cave by man, although, of course, there is some flesh on them. Indubitably, cave-dwelling carnivores intermittently added to the faunal aggregate of the cave material.

Mammals represented in the topmost or recent level of the Sandia Cave are listed below in order of the numerical importance of the bones represented, although this is only an approximation of the true relationships, as the collection contained many unidentifiable fragments.

Wood rat (*Neotoma* sp.)
Bat (*Tadarida mexicana,* also other sp.)
Mountain sheep (*Ovis canadensis*)
Elk (*Cervus* sp.)
Mule deer (*Odocoileus* sp.)
Ground sloth (*Nothrotherium* sp.)
Porcupine (*Erethizon* sp.)
Bear (*Ursus* sp.)

Mammal material from the Folsom layer includes the following, also roughly in order of importance:

Horse (*Equus* near *occidentalis*)
Camel (*Camelops* sp.)
Bison (*Bison,* near, but smaller than, *taylori*)
Mammoth (*Elephas* sp.)
Ground sloth (*Nothrotherium* sp.)
Wolf (*Canis,* cf. *lupus*)

The Sandia layer includes in its faunal assembly the following:

Horse (*Equus excelsus*)
Bison (*Bison antiquus*)
Camel (*Camelops* sp.)
Mastodon (*Mastodon americanus*)
Mammoth (*Elephas* sp.)

Outstanding among the considerations brought to light by this faunal assemblage is the occurrence of ground sloth on top of the crust in the lower portions of the recent layer. Several specimens attributable to sloth, including one claw core, were found in the rear of the cave directly on top of the travertine layer. As these were mingled with no human artifacts, the supposition is that the material was deposited by animals actually lairing in the cave. It has been already ascertained from the Gypsum Cave studies (Harrington, 1933) that ground sloths of the genus *Nothrotherium* habitually frequented caves. Because of the stratigraphic sequence in Sandia Cave, this adds valuable weight to the theory that the ground sloth lingered into early Recent times.

The remainder of the fauna of the recent layer is not at all remarkable and can be duplicated in any of the other caves of the Sandia

group (in none of the other Sandia caves does sloth appear in the recent level). Both mountain sheep and elk have long been absent from the Sandia and Manzano regions, although the former has recently been reintroduced. Indeed, no species of elk has ever been recorded from the Sandia Mountains, presumably having become extinct at a very early date.

The fauna of the Folsom layer adds no radically new information to our knowledge of that period. Although this assemblage is comparatively large, associations of Folsom or Folsomlike material have been made with each of these mammals. Only the sloth is peculiar in this particular, but previous knowledge of the time in the Pleistocene occupied by the sloth readily admits of this association. Conkling Cavern (Conkling, 1932) also featured sloth with horse and camel. The sloth, in this instance, might argue a late date for the Folsom material from Sandia Cave.

The bison of the Folsom layer is believed by Gazin to be slightly smaller than the classic *Bison taylori* which normally accompanies Folsom material as at the type site at Folsom, N. Mex. The comparative scarcity of bison in the Folsom layer of the cave may be attributed to the character of the surrounding terrain, which is only partially Plainslike and consequently not particularly well adapted for bison habitat.

The Sandia layer is chiefly distinguished by the addition of the mastodon and the deletion of the sloth. It has been generally supposed—and this seems to be borne out in this instance—that the ground sloth was late Pleistocene and early Recent in date. The mastodon, however, has also been found in assemblages which indicate that it may have lasted late in some areas. The absence of the mastodon in the upper levels of Sandia Cave may indicate nothing, as a number of bone fragments referable to Proboscidia were unidentifiable.

Equus excelsus from the Sandia stratum has so far not been differentiated from the *occidentalis* form of the Folsom level. *Excelsus* is based upon material from Hays Springs, Nebr. It is believed to be very close to *Equus complicatus*. Indeed, some authorities believe that the original type material should have been so termed. Leidy (Gidley, 1901, quoting Leidy, 1869, p. 267) believed *occidentalis* indistinguishable from *excelsus*. Both forms are similar and close to *complicatus*. Both of these horses are medium-sized Pleistocene forms with possibly some differentiation in range. *Excelsus* has heretofore been considered a Plains type, whereas *occidentalis* has been thought of as coastal in distribution.

MANZANO CAVE

As previously mentioned, certain caves in the Manzano region south of the Sandia Mountains give indication of fitting in and adding to the Sandia sequence. One of these, especially, termed Manzano Cave, is the most important of this group. This cave is located 5 miles to the west of the small town of Manzano in the limestone foothills of the Manzano Mountains. Manzano Cave is considerably larger than Sandia Cave in general dimensions, although not nearly so long. This cave was brought to our attention in 1939 by guano diggers operating from the town of Manzano. One of these, M. Garcia, brought to the Museum a side-shouldered point apparently belonging to the Sandia complex (pl. 14, fig. 1, *d*). Spurred by this discovery, the University of New Mexico made some investigations in the cave. Unfortunately, however, digging operations by the local people had progressed so far that only a small portion of the original deposits remained. These were dug over with care and some information gleaned.

Manzano Cave contains a stratigraphic sequence which may parallel that of the Sandia site. On top is a recent deposit of considerable depth made up of dirt in sections where the cave is damp, and of guano where it is dry. This deposit, in places where it can still be measured, is over 2 meters thick. Below the recent deposit extends a layer of disintegrated limestone of sandy consistency, intermingled with small limestone fragments. This was cemented into a solid mass by calcium carbonate. This breccialike layer was 1 meter thick (slightly less in some places) and extended over the entire cave floor, apparently corresponding to the travertine layer of Sandia Cave. As far as could be ascertained, this layer was devoid of cultural content, although some unidentifiable bone fragments were recovered. Below the cave breccia occurred a layer of stratified disintegrated limestone mingled with lenses of yellow ochre. This stratum of varying thickness was also sterile. Mr. Garcia assured us that it was below the yellow ochre layer that he obtained the Sandia point. No excavations were made by our expedition beneath the yellow ochre because of the already disturbed nature of most of the deposits.

In a segment of Manzano Cave, on the west side of the main chamber, was recovered a quantity of cultural material embedded in rock fragments and limestone debris intermixed with disintegrated and amorphous dung. This section, less rich in returns, had been undisturbed by either the guano hunters or the relic hunters. In this small segment, on top of the cave breccia, and at the base of the accumulation of recent material, were found a number of stone balls

and three projectile points. The only bones identified from this section were those of *Camelops* and *Nothrotherium*.

The projectile points are not arrowheads, and because of similar outline and technique, may be ascribed to the type known as Gypsum Cave points (Harrington, 1933, figs. 53, 54, and 55). Plate 14, figure 1, *a, b, c,* shows these to be remarkably similar to the atlatl points recovered by Harrington at Gypsum Cave, except that the Manzano specimens seem to have considerably more flare and definition of the shoulder. Because of their position in the cave debris and other associations, they may be attributed to a horizon corresponding with that of the Gypsum Cave material and may be contemporaneous with the sloth.

The stone balls found in this same area and at this level, add a different note to the picture. Three of these were found together and apparently represent a set (pl. 14, fig. 2, *a, b, c*). These are of approximately the same size (4 cm. in greatest dimensions), and are of equal weight (2 oz. each). Each of the three has a well-defined groove completely encircling it. All are of limestone, one of them containing a small fossil shell, apparently a brachiopod. One of the balls is of a decidedly reddish cast. After consultation with Junius Bird in connection with his South American explorations, where such things are common, these balls have been identified as bola balls.

In this same excavation two other balls apparently belonging to the same category were found. One of these is of limestone and the other a fragmentary specimen of granite. The granitic bola is grooved (pl. 14, fig. 2, *d*), the limestone one smooth and ungrooved. The limestone ball is 5 centimeters in diameter and weighs $5\frac{1}{2}$ ounces.

Since the initial discovery a number of these stone balls, both grooved and ungrooved, have turned up. Some are slightly pear-shaped with a notch or pit in the pointed or elongated section.[7] Materials vary from limestone to granitic and volcanic rocks, with limestone the favorite.

Balls of this sort are not unusual in Southwestern collections, although their identification as bola weights has seldom heretofore been suggested.

Isleta Cave

Another cave in the vicinity of Albuquerque adds some weight to the chronological picture of the Sandia-Manzano-Albuquerque

---

[7] Mr. Bird has pointed out that this pit was for the accommodation of a knotted thong by which the bola ball was secured. See Bird, 1938, p. 17.

region. This site, known as Isleta Cave, is totally different in nature from either the Sandia or Manzano cave groups. Isleta Cave is located in the lava fields on the west side of the Rio Grande River approximately 10 miles due west of the pueblo of Isleta, on the Isleta Indian Reservation. This cave was also made known by guano hunters working under lease from the Isleta Indians.

Isleta Cave is a blowhole in the lava, one of those cavities so frequent in lava fields, and is of unusual size. The entrance is vertical, extending straight down through the oculus for a distance of 9 meters to the debris below. The major cave chamber itself is of considerable size, measuring some 20 meters in its greatest dimension north to south. Leading off from the main chamber are two passageways or enlarged cracks in the lava extending southeast and southwest. The southeastern one, especially, extends for a considerable distance— some 100 meters—and ends finally in a series of smaller fissures and cracks, which have not as yet been fully explored.

Amidst jumbled lava blocks in the east passage, unfortunately the area most disturbed by the guano hunters, were cultural and faunal evidences that shed some light on the prehistory of the region. Students from the University first recovered a series of atlatl shafts with the typical cupped butt and detachable foreshaft arrangement. In addition, there was a series of large bones accompanying the atlatl remains, but their exact relationship is uncertain, because of the disturbance. Subsequent explorations in the cave, although still of a preliminary nature, revealed other evidences. Flint material, which has been found for the most part around the cave mouth and never in association with atlatl fragments, consists of Folsom-shaped points and some 40 small snub-nosed scrapers. These evidences are nonconclusive and are quite as baffling as the classic "blow-out" sites of the Plains region. Faunal material from the cave, some of it found between lava fragments and in crevices immediately on the surface, includes the following:

Bison (*Bison* sp.)
Camel (*Camelops* sp.)
Mammoth (*Elephas* sp.)
Horse (*Equus* sp.)
Bear (*Ursus* sp.)
Lion (*Felis* sp.)
Lynx (*Lynx* sp.)
Antelope (*Antilocapra?*)

The faunal assemblage from Isleta Cave, although of uncertain association at the present writing, gives evidence of being late Pleisto-

cene in character and adds to the Paleo-Indian material already collected in this area.

Small test pits in portions of the cave that appear to be least disturbed indicate a stratigraphy varying greatly from that of either Sandia or Manzano Caves. The almost complete disappearance of the recent layer may, of course, be attributed to the operations of the guano hunters. There is no travertine crust or anything corresponding to it, undoubtedly owing to the fact that the cave is formed in basalt which is practically insoluble. No definite Pleistocene cultural layer may be differentiated at the present time. Cultural material and bones of extinct mammals are mixed indiscriminately among large fragments of lava which defy stratigraphic differentiation.

SUMMARY AND CONCLUSIONS

During the seasons of 1936, 1937, 1938, 1939, and terminating in 1940, the University of New Mexico excavated a cave known as Sandia Cave, located in Las Huertas Canyon in the north end of the Sandia Mountain region just to the east of Albuquerque, N. Mex. In addition, Davis Cave and Guano Cave, two other cavities of the Sandia group, were partially excavated. One cave in the Manzano region, Manzano Cave, was tested, and another, Isleta Cave, was partially explored.

The findings in Sandia Cave are of major importance. The cave fill was stratified, with definite cultural objects in various strata, some of which could be identified as paralleling certain other known culture horizons. In the very mouth of the cave modern material was present in the form of potsherds. These are of black-on-white types of the Pueblo III period and late Glaze wares such as occur at Pueblo IV and Pueblo V sites in the Rio Grande Valley and in the Galisteo district. Other recent accumulation was represented by deposits of guano and pack-rat debris, diminishing toward the rear of the cave. Beneath this modern deposit extended a sheet of cave travertine or calcium carbonate representing a wet period preceding the recent. This calcium crust seems to represent roughly the end of the Pleistocene. Beneath this cave crust lies the uppermost of the two main cultural horizons. This one is termed the Folsom occupation because of included artifacts. It is characterized by loose debris cemented into a breccia by calcium-charged waters percolating from above. Below the Folsom floor is a sterile laminated stratum of yellow ochre representing another and earlier wet phase. Below the yellow ochre is the Sandia layer, the earliest cultural stratum of

the site. The Sandia layer is less consolidated than the Folsom and contains fire areas or hearths. Below the Sandia occupation, between the Sandia and bedrock, lies an intermittent layer of disintegrated limestone of claylike consistency.

Artifacts of the Folsom layer comprise a series of tools and implements, including Folsom points and other objects considered typical of Folsom times. Classic Folsom points are represented by two whole points and two bases. Three unchanneled Folsom-shaped points are present, as well as one lanceolate Southern Plains type. Five large blades, six gravers, seven snub-nosed scrapers, four side scrapers, ten flake knives, one ivory shaft, and two worked splinters of bone make up the rest of the Folsom series.

The Sandia layer is equally distinctive. Sandia points are generally larger than typical Folsoms, and not so well chipped. These earlier points are distinguished by a side shoulder or notch suggestive of Solutrean points, although no contemporaneity or connection between them and the Old World forms is necessarily implied by such comparison. The Sandia points are further divided into two subtypes, both possessing the side-shouldered feature. Type 1 is lanceolate and rounded in outline. Type 2 is straight-shafted with paralleling sides. Type 1 is apparently slightly older than type 2. The rest of the Sandia collection comprises three snub-nosed scrapers, one side scraper, numerous flakes which may or may not have been used as knives, and two bone points.

Twelve species of animals are present in all the strata of Sandia Cave. In the recent layer, only the ground sloth is an extinct member. Sloth remains were found only in the lowermost portions of the recent deposit and in the rear of the cave. The Folsom layer is distinguished by horse, camel, bison, mammoth, ground sloth and wolf. The Sandia stratum includes in its faunal assemblage horse, bison, camel, mastodon, and mammoth. The paleontological grouping of Sandia Cave is chiefly valuable as contributing to knowledge of late Pleistocene and early Recent times. None of the species are particularly distinctive nor are the associations new. The sloth is again indicated as one of the last survivors of the many large Pleistocene mammals which became extinct at the end of that period and in the beginning of the Recent.

Sporadic testing in other caves of the Sandia-Manzano area, especially at the site known as Manzano Cave, has produced further results. In Manzano Cave strata were found which correspond roughly with Sandia material. In addition, a cultural level was segregated which may be described as early Recent, i.e., following the

Folsom. This later-than-Folsom culture is identified by a type of projectile point similar to those of Gypsum Cave, Nevada. In addition to a distinctive type of projectile, the Manzano Cave also produced spherical and sometimes grooved stone balls identified as bola weights.

In this region, then, and perhaps with validity applicable to a much larger area, a sequence has been erected. This is especially important as it involves the famous Folsom culture, already the center of a controversy concerning the antiquity of the Paleo-Indian in North America. The various components of the sequence occur in the following order:

```
            Recent Pueblo occupation
            Considerable time interval
            Manzano (Gypsum Cave)...............Early Recent
            Wet period ...........................End of Pleistocene
            Folsom ...............................Late Pleistocene or
                                                       early Recent
            Wet period ...........................Late Pleistocene
            Sandia ...............................Late Pleistocene
```

This sequence involving an earlier-than-Folsom culture again brings to the fore the question of Old World connections. This problem is rendered the more pressing by reason of the remarkable resemblance between the Sandia points and certain Solutrean examples from the Old World. It has already been pointed out by many of those interested (McCown, 1939, pp. 150-152) that Solutrean cultural relationship is not to be suggested in the case of Folsom man because of the remoteness of true Solutrean (almost entirely within continental Europe) and the complete lack of demonstrable connection between Solutrean regions and the New World across the as yet unknown reaches of Asia. The perhaps fortuitous circumstance that the Sandia projectile points even more closely resemble certain Solutrean examples brings this question even more prominently to the fore. It is well known by those who have studied Solutrean collections in Europe that the bulk of the material is not distinguished by fine ripple flaking and delicately made points à cran. Indeed, European Solutrean is much closer to the Sandia than to the Folsom, especially as the Folsom is distinguished by a specialized facial channel unparalleled in European or Asiatic horizons. However, it is fruitless to discuss Solutrean connections or contemporaneity until Asiatic gaps of awe-inspiring magnitude have been bridged, a possibility at the present time extremely remote.

A school of thought advocating a Neolithic basis for all New World cultures exhibits an equal academic myopia concerning cultural phe-

nomena as they are now known. Although some "Neolithic" cultures are known which existed on a hunting and fishing economy, their inclusion in Neolithic categories is dependent upon agricultural and animal husbandry centers in adjacent territories known to be contemporaneous. In other words, the classic text-book sequence of culture for Europe has already been demonstrated to be invalid for Asia, especially Siberia. Furthermore, rudimentary studies of agriculture show that of the New World to be distinct from that of the Old World both in the matter of species of plants and of methods. It must not be forgotten that the word Neolithic was coined for European problems originally and was brought into the New World to describe the status of the recent American Indian, which apparently paralleled certain European and Asiatic groups. This status in the Old World included agriculture, animal domestication, permanent habitations, bow and arrow, pottery, etc., all of which are lacking in the cultures now in question. Furthermore, the Neolithic even in Mesopotamia, its supposable point of origin, was definitely subsequent to the pluviations and climatic fluctuations attendant on the last retreat of the Würmian glaciation in its various stadia. There is no reason to believe that the continental glaciations in North America were not contemporaneous with those of Europe (Daly, 1934) stage for stage, although minor variations may have been localized in one hemisphere.

Folsom and Sandia have been definitely associated with extinct mammal forms and with climatic changes coincident with the last phases of the Wisconsin glaciation. There is no reason to deny these New World cultures an antiquity comparable with European and Asiatic cultural phenomena occurring under similar climatic circumstances and accompanying a like fauna. There is no need for correlations with definite European cultures especially by name, or even Asiatic ones. Horizons roughly corresponding to Folsom and Sandia have been described from southern and eastern, but not as yet northeastern, Siberia. These are usually lumped under an "Upper Paleolithic" category which is descriptive of a cultural status and time rather than of a European connection by name, although the blade industries of the European levels and the Near East are also represented in Asia (elaborations and variations of Aurignacian, Aurignacian-Magdalenian, and Gravettian). There seems little need to connect New World cultures, whether Sandia, Folsom, or any other, with Asiatic or European cultures when intervening areas, i.e., eastern and northeastern Siberia, are not known. Even Alaska

is comparatively untouched as far as the question of the Paleo-Indian is concerned.

It is becoming more apparent, as a cultural sequence is being evolved for North America, that the first hunting groups of the New World arrived here in times corresponding to the Upper Paleolithic of Europe and Asia and with a tradition of flint chipping comparable with Siberian centers of the same age.[8] The famous facial channel that distinguishes the Folsom point is but a refinement of a blade-making technique that is, after all, the real basis of differentiation of some of the Old World Upper Paleolithic movements and changes. The Folsom graver is an instrument comparable to a burin although lacking the burin stroke. Refinements of basal technique, such as the striking off of blades, would logically differ in application in widely separated locales especially if contact with the points of origin had long been lost. We may postulate on this basis with fair certainty that the first comers to this continent came armed with a knowledge of blade making and a rudimentary idea of pressure flaking as well. The final development of this blade-making tradition was brought to an admirable conclusion in Neolithic Mexico as well as in Neolithic France (Grand Pressigny). Sandia and Folsom types of flint work represent some of the first variations on these basic techniques in the New World. If the Solutrean was a European outgrowth of this development in one direction, the New World manifestations may be logically suggested as an outgrowth in another, with no direct connection with or knowledge of the Solutrean implied. Climatic and faunal considerations all argue for a similar age. Indeed, it is becoming more evident that both Lower and Upper Paleolithic horizons in Europe, Africa, and Asia represent variant manifestations of the development of a few basic forms, such as the fist ax, the side scraper, and the blade.

In all considerations, the Sandia and Folsom aspects manifest themselves as Upper Paleolithic in character, but with no connection with Asiatic or European phases of specific nature beyond a common sharing of some basic ideas such, for example, as the blade.

BIBLIOGRAPHY

ALBRITTON, CLAUDE C., JR., and BRYAN, KIRK
    1939. Quaternary stratigraphy in the Davis Mountains, Trans-Pecos, Texas.
        Bull. Geol. Soc. Amer., vol. 50, pp. 1423-1474.

---

[8] Mal'ta on left bank of Belaya River near Lake Baikal. Obermaier, 1928; Petrie, 1932.

ANTEVS, ERNST
 1937a. Climate and early man in North America. *In* Early man as depicted
   by leading authorities at the International Symposium, Academy
   of Natural Sciences, Philadelphia, pp. 125-132, March.
 1937b. Studies on the climate in relation to early man in the Southwest.
   Carnegie Inst. Year Book No. 36, p. 335.
 1938. Studies on the climate in relation to early man in the Southwest.
   Carnegie Inst. Year Book No. 37, p. 348.
BIRD, JUNIUS
 1938. Before Magellan. Nat. Hist., Amer. Mus. Nat. Hist., vol. 51, No. 1,
   pp. 16-29, January.
BIRD, JUNIUS and MARGARET
 1937. Human artifacts in association with horse and sloth bones in south-
   ern South America. Science, vol. 86, No. 2219, July 9.
BROWN, BARNUM
 1929. Folsom culture and its age. Bull. Geol. Soc. Amer., vol. 40, pp.
   128-129.
BRYAN, KIRK
 1937. Ancient man in America. Geogr. Rev., vol. 27, pp. 507-509.
 1939. Stone cultures near Cerro Pedernal and their geological antiquity.
   Bull. Texas Archeol. and Paleont. Soc., vol. 2, pp. 9-43, September.
CONKLING, R. P.
 1932. Conkling Cavern. The discoveries in the bone cave at Bishop's Cap,
   New Mexico. West Texas Hist. and Sci. Soc., Bull. 44, p. 4.
COOK, H. J.
 1927. New geological and paleontological evidence bearing on the antiquity
   of mankind. Nat. Hist., Amer. Mus. Nat. Hist., vol. 27, No. 3,
   pp. 240-247, May.
DALY, REGINALD
 1934. Changing world of the Ice Age. Yale Univ. Press.
ELLIS, H. HOLMES
 1940. Flint working techniques of the American Indians: An experimental
   study. Ohio State Archeol. and Hist. Soc., Ohio State Mus., April.
ELLIS, ROBERT W.
 1922. Geology of the Sandia Mountains. Bull. State Univ. New Mexico,
   Whole No. 108, Geol. Ser. 3, No. 4, September.
FIGGINS, J. D.
 1927. The antiquity of man in America. Nat. Hist., Amer. Mus. Nat. Hist.,
   vol. 27, No. 3, pp. 229-239.
GIDLEY, J. W.
 1901. The North American species of Equus. Bull. Amer. Mus. Nat. Hist.,
   vol. 14, pp. 91-143.
HARRINGTON, M. R.
 1933. Gypsum Cave, Nevada. Southwest Mus. Pap., No. 8.
HOWARD, E. B.
 1935. Evidence of early man in North America. Mus. Journ., vol. 24,
   Nos. 2-3, pp. 61-176, Univ. Mus., Univ. Pennsylvania.
KIDDER, A. V., and SHEPARD, A. O.
 1936. The pottery of Pecos, pt. 1. Yale Univ. Press.

LEIDY, JOSEPH
 1869. Extinct mammalian fauna of Dakota and Nebraska. Journ. Acad.
   Nat. Sci. Philadelphia, ser. 2, vol. 7, pp. 257, 267, 331, 399, 401.
MACCURDY, GEORGE GRANT
 1932. The coming of man. Univ. Soc., New York.
 1937. Early man as depicted by leading authorities at the International
   Symposium, Academy of Natural Sciences, Philadelphia.
MCCOWN, T. D.
 1939. The magic word, Solutrean. Amer. Antiquity, vol. 5, No. 2,
   pp. 150-152.
MERA, H. P.
 1935. Ceramic clues to the prehistory of north central New Mexico.
   Lab. Anthrop., Techn. Ser., Bull. No. 8, Santa Fe, August.
OBERMAIER, H.
 1928. Realexikon der Vorgeschichte, vol. 12, pp. 55-57. Verlag, Walter
   de Gruyter, Berlin.
PETRIE, E. B.
 1932. The Paleolithic in Siberia. Proc. First Int. Congr. Prehist. and Proto-
   hist. Sci., p. 87.
ROBERTS, F. H. H., JR.
 1935. A Folsom complex: Preliminary report on investigations at the
   Lindenmeier site in northern Colorado. Smithsonian Misc. Coll.,
   vol. 94, No. 4, June 20.
 1936. Additional information on the Folsom complex: Report on the
   second season's investigations at the Lindenmeier site in northern
   Colorado. Smithsonian Misc. Coll., vol. 95, No. 10, June 20.
 1939. On the trail of ancient hunters in the western United States and
   Canada. Expl. and Field-Work Smithsonian Inst. in 1938,
   pp. 103-110.
 1940. Developments in the problem of the North American Paleo-Indian.
   In Essays in historical anthropology of North America, Smith-
   sonian Misc. Coll., vol. 100, pp. 51-116.
SELLARDS, E. H.
 1940. Early man in America. Bull. Geol. Soc. Amer., vol. 51, pp. 373-
   432, March.
STRONG, W. D.
 1935. An introduction to Nebraska archaeology. Smithsonian Misc. Coll.,
   vol. 93, No. 10.
WORMINGTON, H. M.
 1939. Ancient man in North America. Colorado Mus. Nat. Hist., Pop. Ser.,
   No. 4.
WRIGHT, WELTY
 1940. The type, distribution and occurrence of flint gravers in Texas.
   Bull. Texas Archeol. and Paleont. Soc., vol. 12, pp. 31-49.

CORRELATION OF THE DEPOSITS OF SANDIA CAVE, NEW MEXICO, WITH THE GLACIAL CHRONOLOGY

By KIRK BRYAN

Harvard University

INTRODUCTION

The present report is based on brief visits to Sandia Cave in 1939 and 1940. It gives a geologic interpretation of the bedded cave deposits containing artifacts of the Folsom and heretofore unknown Sandia complex, both associated with the bones of extinct animals. The excavator of the cave, Dr. Frank C. Hibben, has described and discussed the cultural and animal remains and their archeological relationships. Hence the following paper is concerned mainly with the geologic aspects of the cave and an attempt to correlate the deposits with the glacial chronology.

This correlation leads to the conclusion that the artifact-bearing cave deposits were laid down during a time of greater moisture corresponding to the last ice advance of the Wisconsin stage of glaciation. The climax of this episode is represented by the sterile ochre deposits, which therefore have a nominal date in the accepted chronology of 25,000± years. People of the Folsom culture lived in the cave just later than, and those of the Sandia culture just previous to, this nominal date.

METHODS

The age of cave deposits is a problem that can rarely be solved by a direct attack. In general, as Dr. Hibben has already suggested, cave deposits have no physical connection with any deposits in the locality beyond the cave mouth. Hence the sequence of events recorded in the cave is not directly connected with other sequences that took place outside its limited and special space. In a few instances gravels and sands deposited by the sea or by ancient lakes have been deposited in caves. Such deposits give a sure connection with at least one event in a sequence of events in the outside world. Usually, however, general arguments are the only recourse in attempts to date cave deposits.

45

The contained human or animal remains may afford a partial or complete correlation with known geologic horizons. In North America the present rapidly expanding knowledge of ancient cultures and of Pleistocene vertebrates gives hope that this type of correlation will soon be more perfect than at present. If, however, the cave deposits can be interpreted as representing a sequence of events related to or in part the result of climatic fluctuations, an independent line of inquiry is available. The climatic implications of cave deposits may then be related to the rhythm of climatic fluctuations of the past. Thus a connection may be made with a general and world-wide chronology— the pulsations of climate characteristic of the Pleistocene.

Such a line of argument has obvious and unescapable faults. If the sequence of events within the cave based on the cave deposits is unassailable, the interpretation of the deposits in terms of climate may be faulty. If the latter is correct, it is always possible that the correlation with the general climatic rhythm is incorrect. Furthermore, our knowledge of the climatic rhythm, the number, length, and amplitude of its fluctuations, is still imperfect. As further knowledge of the Pleistocene and particularly of the late Pleistocene is acquired, the precision of the chronology of climatic fluctuations will increase. Present correlations may be confirmed or may be shifted, either forward or backward. In the meantime the use of the method is amply justified provided it is thoroughly checked against the anthropological probabilities. When, in the future, successive new localities provide a complete archeological sequence, the correlations based on reference to the general chronology of climatic pulsations will have an adequate frame of reference.

FACTS TO BE EXPLAINED

Sandia Cave and its deposits present for analysis and explanation a large array of geologic facts. These facts, mostly obtained by Hibben's excavations and recorded by him in detail in preceding pages, are here summarized for convenient reference.

The cave lies high on the steep eastern wall of Las Huertas Canyon, at an altitude of 7,275 feet, in the northern portion of the Sandia Mountains in Bernalillo County, N. Mex. (fig. 1, p. 4). It is 4 miles upstream from the village of Placitas (fig. 8). The cave is tunnel-like and extends eastward from its opening on the cliffy face of the limestone ridge that forms the eastern side of the canyon. The mean diameter is 7 to 10 feet (2 to 3 m.) and the mean slope is 72
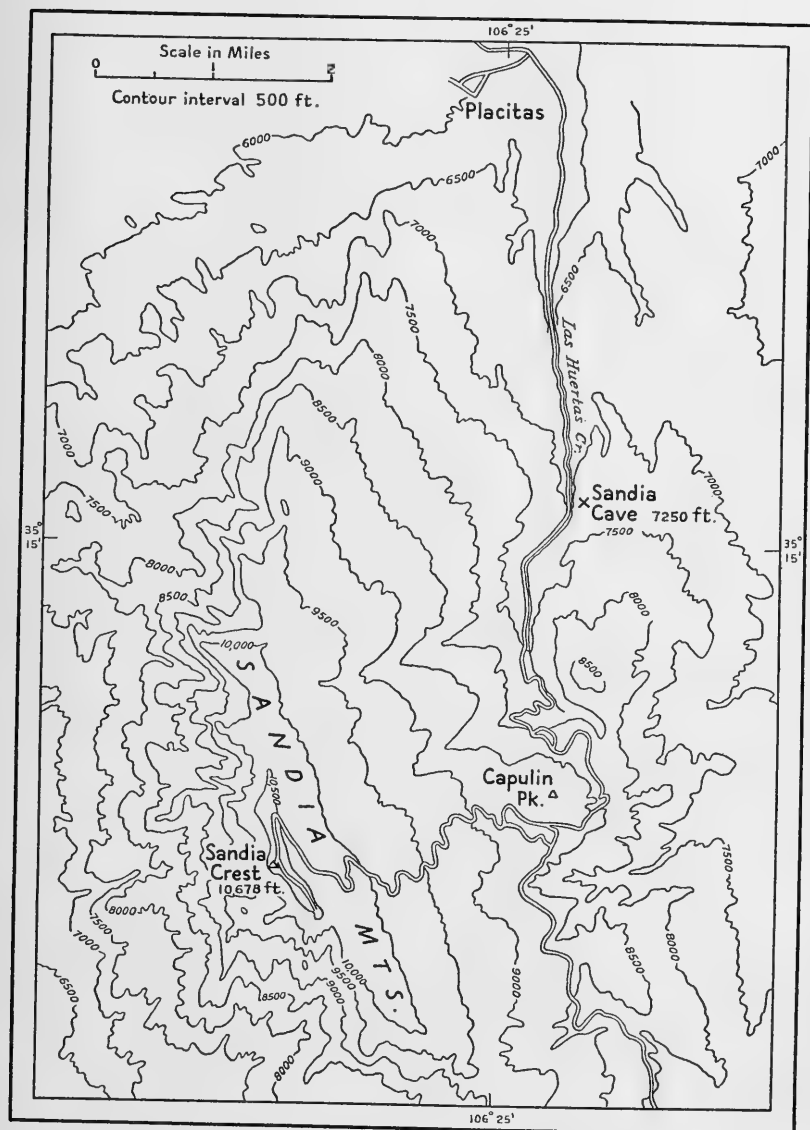
Fig. 8.—Northern portion of Sandia Mountains showing position of Sandia Cave with respect to Las Huertas Canyon and Sandia Crest. Redrawn from the U. S. Forest Service map of the Cibola National Forest, 1936.

feet (22 m.) in 453 feet (138 m.) or approximately 9 degrees, some-what less steep than the dip of the limestone beds so that the cave begins in one bed and ends in a higher one. The beds belong to the Magdalena formation of Pennsylvanian age. As shown in the cross section, figure 5 (p. 12) in Hibben's report,[9] the cave is overlain by great thicknesses of limestone ranging from 50 feet (15.2 m.) at the opening to nearly 200 feet (61 m.) at the point 453 feet (138 m.) from the face where the cave closes in and beyond which it has not been explored. The cave at present is dry. In the first 328 feet (100 m.) the floor is dusty. Farther within and downward the dust will not lift from the floor, but the cave is not damp enough for moisture to be noticeable on the walls until the end of the explored portion is reached.

The deposits of the cave near its mouth consist of the following beds:

DEPOSITS OF SANDIA CAVE

(Arranged in order from top to bottom)

f. Dust, guano, and trash: decreasing in thickness from about 6 feet near the mouth to a thin layer of dust at meter 70. Contains pottery (late Glaze) of early Spanish or immediately pre-Spanish date (A. D. 1400-1600).

e. Stalagmite layer: 6 inches to paper thinness; granular and crystalline tex-ture; in places "chalky;" the surface marked by small Tivoli-type cups. Contains a few stones and in places is broken by falls of blocks from the roof.

d. Upper cave breccia: 1 to 4 feet thick; consists of fragments of limestone, rounded and irregular masses of yellow ochre, fossil bone, artifacts, and charcoal, but no hearths; cemented by crystalline calcium carbonate which forms parallel films and stalagmite layers and also surrounds many indi-vidual fragments. Artifacts absent beyond meter 83.

c. Yellow ochre: 2 inches to 2 feet thick; consists of nearly uniformly fine-grained yellow ochre (limonite) banded and laminated, with a few thin layers of chalky granular calcium carbonate. No fossil bone, artifacts, or limestone fragments.

b. Lower cave breccia: 0 to 3 feet thick; consists of fragments of limestone, rounded and irregular fragments of limonite especially near top; fossil bone, artifacts, hearths, and charcoal; in places not cemented at the base, and in every place more cemented at and near the top by finely granular calcium carbonate. Hearths limited to first 15 meters of the cave.

a. Basal clay: 0 to 2 feet thick; gray clay with loose crinoid stems and with fragments of limestone showing solution surfaces; occurs mostly in de-pressions of the floor.

---

[9] The faults shown in figure 5 were not mapped by the writer.

The cave and its contained deposits imply that the following events have occurred:

1. Period of cave formation.
2. Long interval of time.
3. Accumulation of basal clay. Entrance presumably closed as there is no occupation; perhaps overlapping with period 2.
4. Accumulation of lower cave breccia. Entrance open, occupation; increasing quantities of water dripping from the roof and producing cementation of breccia by reason of its contained calcium carbonate. Iron oxide (yellow ochre) also deposited in shallow pools. Strong evaporation.

    Open entrance chamber in which people lived and built fires. Hearths extend back into present cave. Bones and artifacts in part refuse that drifted down sloping floor of cave from living space which no longer exists.
5. Accumulation of yellow ochre. As this material is free of fossil bone and artifacts the entrance must have been closed or the drip from the roof so severe that the entrance chamber was uninhabitable. Closure by a rock fall would seem to be indicated as reduced air movement would inhibit evaporation and warming of the air with consequent deposition of calcium carbonate. It would also inhibit frost action near the mouth of the cave and therefore the production of fragments of rock that would slide down the slope. The factor of closure seems inadequate to explain the almost exclusive deposition of ochre and a strong drip, and therefore moister conditions are implied.
6. Accumulation of upper cave breccia. Entrance open. Strong drip from the roof depositing calcium carbonate and iron oxide. Cementation greater than in lower breccia. Zones of stalagmite in places.

    Open entrance chamber. No hearths within present cave. Fossil bone, artifacts, and many rock fragments, largely camp refuse which moved down sloping floor of cave from living space which no longer exists.
7. Deposition of stalagmite layer. The entrance was closed or inaccessible to man and animals, as supply of refuse ceased. It seems likely that a rock fall occurred by which the entrance chamber was sheared off and the cave became inaccessible but with free air circulation. The drip from the roof deposited the stalagmite layer but gradually ceased. Parts of the stalagmite layer consist of thin chalky plates implying deposition of calcium carbonate from weak drip under strong evaporation. Occasional rock falls during and after deposition of stalagmite.
8. No deposition over a long period. Entrance presumably closed and cave dry without drip from the roof.
9. Accumulation of guano and dust. Cave open and first 70 meters partly filled by wind-borne dust, bat and rat guano. During part of the time, used by the Pueblos as an occasional camping place.

CLIMATIC INTERPRETATION

The period of formation of the cave falls in a relatively remote period. At present, the roof consists of firm rock from which only a few fragments can be detached. Below meter 150 there are open-

ings in the rocks extending downward and a strong air movement. As this area is damp, enlargement may be going on at present. Obviously the explored portion of the cave is not now being enlarged. Nor has it been much enlarged since the beginning of the period in which the cave deposits were accumulated. The excavation record shows that here and there blocks have fallen from the roof, but there has been no substantial growth of the cave since its original formation.

The formation of the cave must have required the movement of relatively large quantities of water through it. To account for large quantities of water it would seem necessary to suppose that Las Huertas Canyon did not exist or at least was much shallower than at present. If the floor of the canyon lay at an elevation above the cave an ample supply of water would be available for circulation down the eastward-dipping rocks. The limestone might by such a mechanism be dissolved and the cave formed.

The formation of the cave is thus remote in time. The period of occupation is comparatively recent. Between the period of formation and the beginning of deposition in the cave, there must have been a long interval of time. The cave and the cave deposits afford no evidence concerning the events or the climatic character of this interval.

The cave deposits begin with the basal clay, a discontinuous body which lies largely in the depressions of the floor. This clay is the residuum from solution of limestone—the less soluble parts of the original rock. It was presumably slowly accumulated, for if large amounts of water had been available, it seems probable that the clay would have been washed away. Presumably also the available water was not evaporated, or calcium carbonate would have been deposited.

Under present conditions, there is no visible inflow of water into the cave; the floor is largely dry but there is a strong draft of air. If the entrance were closed, it might be possible that the whole cave would be slightly damp and that slow solution would occur throughout the cave. Under such conditions, material like the basal clay would accumulate. It may, therefore, be inferred that the basal clay is the record of a climatic period somewhat similar to the present. As this clay is sterile, it presumably accumulated when the entrance was closed.

The lower breccia is largely uncemented at the base. It is a rubble of angular fragments of limestone with fossil bone and a few artifacts. Cementation increases toward the top. The calcium carbonate must have been deposited by drip from the roof, but deposition was rapid and took place under evaporating conditions. The calcium

carbonate is granular and similar to the travertine deposited by lime-bearing spring waters in the open air. The increased amount of calcium carbonate in the upper layers implies that drip from the roof increased during the period of deposition. Limonite in the form of yellow ochre was deposited as laminated plates which were broken up into fragments and deposited as part of the breccia. It is probable that the limonite was first deposited in shallow pools by water which flowed down the sloping floor and built rimmed pools like those of the Tivoli springs. Little cups on the travertine surfaces show this process in miniature. These layers of limonite were presumably broken up by fragments of rock sliding down the slope and also by the trampling of men and animals. The presence of hearths indicates that for a distance of 15 meters from the present entrance the cave was at times dry enough and had a strong enough air current to make it habitable. The larger part of the bones and artifacts forming the breccia, however, were refuse from habitation in an entrance chamber which has now disappeared.

The layer of ochre presents a further problem and implies a change of conditions in the cave. Whereas previously the predominant material deposited was calcium carbonate, and iron oxide was subordinate, during this period conditions were reversed.

The reasons for the deposition of limonite in caves are not completely understood, and the following line of reasoning must be regarded as tentative. The water entering the cave must carry iron in solution presumably as the ferrous carbonate, Fe_2CO_3. In deposition oxygen must be added to form limonite, $Fe_2O_3nH_2O$. The cave must be sufficiently open so that oxygen is available, but some other factor must enter, else calcium carbonate would also be deposited. It seems probable that in this cave the quantity of water increased to such an extent that calcium carbonate was redissolved as rapidly as it was deposited.

The limonite layer contains no bones or artifacts and is also largely free of limestone fragments or roof falls. It must therefore be supposed that the cave entrance was closed or that the cave was so wet that even animals could not live in its entrance chamber. If the entrance were closed, the reduced circulation of air would reduce evaporation of the dripping water and thus inhibit the deposition of calcium carbonate. Thus the sterile layer probably implies a closed entrance and very wet conditions in the cave.

The upper breccia, like the lower breccia, consists of fragments of limestone, fragments of laminated yellow ochre, fossil bone, and artifacts. It is cemented by crystalline calcium carbonate which

5

(1) forms a layer around each fragment, (2) forms lenses within the breccia, and (3) grades upward into the overlying stalagmite layer. The cementing crystalline calcite of the upper breccia must have been deposited by water dripping from the roof and penetrating the mass of rubble. The fact that layers or lenslike masses of crystalline calcium carbonate exist proves that the process of deposition and therefore the drip persisted through the period of accumulation of the upper breccia. Limonite was also deposited in basins but tended to be broken up, and the fragments were incorporated into the breccia. The cave was open and accessible, as animal bones and artifacts of the Folsom culture occur. No hearths or other direct evidence of occupancy have been found, and thus it is reasonable to believe that an outer chamber existed where the people lived and that the upper breccia is essentially camp refuse which migrated down the sloping floor of the cave from this entrance chamber. The crystalline cement of the breccia implies that calcium carbonate was deposited without excessive evaporation and therefore that the drip was stronger and the cave wetter than at the beginning of deposition of the lower breccia.

The upper breccia is capped by the stalagmite layer. This layer, as shown by the excavation record, is variable in thickness and in character. The thickness varies from less than half an inch to 6 inches. In places, especially where it has no great thickness, it consists of paper-thin plates of granular chalky calcium carbonate. In other places it is a crystalline mass of great strength and compactness. In places the surface is marked by Tivoli cups, indicating that water flowed down the slope of the cave. In many places also this layer curves upward near the walls and forms a plaster against them. The stalagmite layer contains a very few small fragments of limestone, but is generally wholly composed of calcium carbonate deposited from solution. Yellow ochre (limonite) is generally absent. In a few places large rocks fallen from the roof have broken the layer. These falls are later than the time of deposition and no recementation has taken place.

It is obvious that during the period of deposition of the stalagmite layer the cave entrance again must have been closed or inaccessible. Whether man was present or not, wild animals would have used the cave had its entrance been open, and their bones or dung would presumably have been preserved. It seems likely that a great rock fall occurred on the east slope of Las Huertas Canyon at the close of the period represented by the upper breccia. The entrance chamber heretofore postulated was sheared off, and the mouth of the

cave closed. Drip of water from the roof, similar to that which went on previously, continued for a time and then gradually ceased. The paper-thin layers formed here and there as the top of the stalagmite layer presumably represent the deposits of the last drip from the roof. In the closed cave deposition ceased, and a long period of time without recorded incident, except occasional falls of roof blocks, ensued.

At the time of the discovery of the cave the opening was choked by a mass of loose material overlying the stalagmite layer. Dust and the guano of bats and rats lay in the mouth of the cave and extended inward with decreasing thickness. Beyond meter 70 there was only a thin line of dust to indicate the layer. Pueblo potsherds were found in this mass. Consequently the use of the cave by Pueblo Indians as an occasional camping place is proved. As shown by Hibben, this occupation was in early Spanish or immediately pre-Spanish time. It is thus implied that a long period intervenes between the closing of the cave at the beginning of stalagmite deposition and the reoccupation at a time when it was as dry as at present and neither solution nor deposition was occurring.

GENERAL CLIMATE IMPLICATIONS OF THE CAVE DEPOSITS

Sandia Cave is now dry, whereas it was once wet. As there is no possibility that water from a stream channel could have been diverted toward it since its formation and original occupation, one must suppose that at one time more water was available on the ridge above than at present. The ridge above is largely bare limestone with a vegetation of scrub oak and scattered pinyons and junipers. The soil, where present, is a loose sandy rubble. There is a marked accumulation of powdery calcium carbonate on all rock fragments at depths of 6 inches to 2 feet below the surface. Thus this ridge has the soils and vegetation characteristic of areas of this altitude in central New Mexico.

For the cave to be wet, it would be necessary for more water to fall as rain or snow on the ridge. This would supply the larger quantities of water to seep downward through the rocks and form a drip. With such an increase in precipitation, there would be consequent changes in the vegetation and the soil.

The nature of these changes may be judged by a consideration of the vegetation on the higher parts of the Sandia Range. The North Peak rises to an altitude of 10,178 feet and lies only 4 miles southeast of Sandia Cave (fig. 8). This peak breaks off sharply to the west and slopes gently to the east and north parallel to the dip

of the limestone beds. The peak is bare of trees, but firs and spruce occur within 50 feet of the top. Apparently the absence of trees on the peak is due to high winds. If the summit were broader, it seems likely that it would have the same dense fir-spruce forest that extends down the east slope.[10] The west slope is mostly bare rock and too steep for the maintenance of soil or forest except in scattered patches of spruce. At lower elevations pines grow in all suitable localities. On the east slope fir and spruce extend as an unbroken forest, except in areas of old burns, down to altitudes of about 8,500 feet. Below this altitude spruce grows in valleys and shaded slopes down to about 7,500 feet. The fir-spruce forest is succeeded below by a pine forest which in this area has been largely destroyed by lumbering and fires. The pine forest extends from altitudes of about 8,500 feet to about 7,500 feet, but groves and single trees exist in shaded places and along streams to altitudes of about 7,000 feet. Below this altitude begins the pinyon-juniper woodland. The foregoing altitudinal boundaries of the forest belts are more or less arbitrarily chosen. In an area where slopes are so steep and where fires have modified the distribution of trees, the vegetation boundaries are not easily traced. Also their lower limits are lower on east-facing and higher on west-facing slopes. Ridges such as that above the cave are relatively exposed and dry and on them the forest boundaries are higher. As previously described the ridge above the cave, although it has an altitude of 7,300 feet, is well within the woodland zone, and the lower boundary of the pine forest lies at an altitude of about 8,000 feet.

Within the area of the forests the soils are markedly different from those in the woodland zone. In the fir-spruce zone, there is below the forest duff a humus-bearing dark silty soil (A-horizon) 3 to 6 inches thick which overlies a more compact brown limonitic and clayey subsoil (B-horizon). The subsoil in places extends down into solution cavities in the limestone bedrock (pl. 15, fig. 1). The walls of the cracks show modern solution, and the brown clay contains roots in part alive and in part quite dead and reduced to humus. There are also fragments of limestone that show active modern solution.

In other localities and deeper in the limestone, limonite rather than clay extends down cracks in the limestone bedrock. On shale outcrops the content of limonite in the subsoil appears to be higher,

---

[10] See photograph of forests and swampy meadows on San Pedro Mountain (altitude 10,600 to 9,600 ft.), looking westward, in figure 8 of Church, F. E., and Hack, John T., An exhumed erosion surface in the Jemez Mountains, New Mexico. Journ. Geol., vol. 47, No. 6, pp. 613-629, 1939.

and below the soil the weathered bedrock has strong limonitic stains in the cracks and joints.

Granite in places is decomposed and stained by limonite to depths of 10 to 20 feet (pl. 15, fig. 2). In Tejano Canyon under a pine forest on granite the soil profile consists of humus-bearing silty soil as much as 6 inches thick. In places it contains fragments of sandstone which have drifted downhill from outcrops of the Magdalena formation above. In this layer, granite is incompletely decomposed, and there are grains of feldspar, but mica is largely absent. The subsoil is of irregular thickness, from 18 inches to 2 feet, and consists of a grit of feldspar and quartz grains embedded in brown clay. The feldspar is mostly a milky white with brown stains and is obviously undergoing chemical decomposition. Mica in this zone seems to be more resistant than in the upper soil but is in part decomposed and has a brownish, limonitic stain. Below these horizons, the lower zone (C-horizon) on steep slopes is colluvial with lenticular zones of coarse debris and occasional sandstone fragments from up-slope in a mass of granite fragments. This more or less colluvial material rests on weathered granite or in places may be absent. The weathered bedrock is disintegrated, in places so much as to be structureless, but elsewhere preserves the joints and minor structures of the original rock. Limonite as a stain and as films in the cracks gives the mass a brownish cast. Soda feldspars are more decomposed than orthoclase. In some localities, as at the head of Las Huertas Canyon (a mile from the junction of the Loop road and the main Tejano Canyon-Ellis Ranch road), the C-horizon consists of slightly weathered granite-gneiss. In the joints limonite is replacing a preexisting red iron oxide.

In the woodland zone soils developed on limestone, and the limestone rubble on steep slopes have an upper light gray A-horizon which is full of stone and obviously incipient with incomplete weathering. The B-horizon consists of a rubble of fragments stained with powdery calcium carbonate. In the deeper rock cuts, the joints show plates of crystalline calcium carbonate with manganese bands and an overlay of powdery calcium carbonate. It is obvious here that the deeper soil solutions once deposited crystalline calcite just as it was once deposited in the cave. At present powdery calcium carbonate is deposited.

The soils of the forest zones, both fir-spruce and pine, as developed on granite and on limestone or shale are pedalfers. Iron and aluminum are concentrated in the B-horizon and extend as films into the cracks or interstices of the C-horizon. Such soils are typical

of humid climates and are the result of the greater precipitation at higher altitudes and the concomitant biochemical processes in the soils developed under a forest cover. The soils are not precisely similar to the soils of a strictly humid climate, because they are subject to prolonged drought conditions, but the main chemical reactions are similar.

The soils of the woodland zone are pedocals—that is to say, calcium carbonate is deposited in the B-horizon. Such soil types are also characteristic of much drier localities and are in marked contrast in their biochemical processes to the pedalfers of the forest zones.

It is also obvious that within the forest zone not only is limestone dissolved by excess water passing downward through the soil zone but that this water carries iron from the B-horizon. The iron is freed from the rocks in the A-horizon and perhaps below it and is temporarily deposited in the B-horizon. It is redissolved in, or perhaps passed through, the B-horizon downward into the underground, where it may be redeposited in the cracks of the rock. This phenomenon explains the presence of ochre in Sandia Cave. The increased precipitation necessary to furnish water to make the cave wet would also clothe the ridge in forest and result in a soil-making process that would furnish iron to the ground water.

The inference that a change in precipitation would also change the character of the soil is confirmed by the existence of the phenomenon of composite soils preserved in favorable places. Thus the occasional presence of red iron oxide in the cracks of the granite within the forest zone records a period in the past when red rather than yellow iron oxide was carried downward by the soil solution. As this process implies a warm humid rather than a cold humid climate, it must date back to one of the interglacial intervals. In Las Huertas Canyon within the woodland zone there are numerous localities where rock cuts show the downward penetration of finely granular calcium carbonate from the modern subsoil. This film of deposition is replacing preexisting films of limonite and coating previously deposited plates of crystalline calcium carbonate. There is thus implied a change in soil type from that of a more humid to that of the present arid climate.

CORRELATION WITH THE GLACIAL CHRONOLOGY

The inference is outlined in the foregoing pages that the cave deposits could have been laid down only under the following conditions: 1, greater precipitation on the ridge above the cave; 2, forest growth on the ridge; 3, pedalfer soils on the ridge to supply iron as well as calcium to the drip in the cave.

A strongly marked and prolonged period of humid climate in a mountainous area of moderate altitude may easily be the local response to the fluctuations of climate accompanying Pleistocene glaciation. If such an assumption is made, which glacial stage is implied? In the southern Rocky Mountains immediately north of Sandia Cave, there were three strong glacial advances and two minor advances in Wisconsin time.[11]

These glacial stages with their presumable American and European equivalents are shown in table 1.

TABLE 1.—*Glacial stages of the last Ice Age in the southern Rocky Mountains and elsewhere*

Short designation	Southern Rocky Mountains	Continental ice of North America	Continental ice of Europe
	Protalus rampart (position uncertain)	Subdivisions not established	Sub-Atlantic Sub-Boreal Atlantic Boreal
W_4	Long Draw	Cochrane	Fennoscandian (moraine)
W_3/W_4	Unnamed interval	Unnamed interval	Gothiglacial Daniglacial
W_3	Corral Creek	Mankato	Pomeranian
W_2/W_3	Unnamed interval	Two Creeks forest bed	
W_2	Home	Tazewell-Cary	Weichsel
W_1/W_2	Unnamed interval	"Peorian"	
W_1	Twin Lakes	Iowan	Warthe

The data on which this table is based are given by Bryan and Ray and by Ray in the papers cited and are not here repeated. It is sufficient to comment on the complications of the last or Wisconsin epoch of glaciation. It was marked by at least three great advances

---

[11] Bryan, Kirk, and Ray, Louis L., Geologic antiquity of the Lindenmeier site in Colorado. Smithsonian Misc. Coll., vol. 99, No. 2, 76 pp., 1940. Ray, Louis L., Glacial chronology in the southern Rocky Mountains. Bull. Geol. Soc. Amer., vol. 51, pp. 185-1918, 1940.

For a review of the European chronology see Zeuner, F. E., The Pleistocene chronology of central Europe. Geol. Mag., vol. 72, pp. 350-376, 1935; The climate of the countries adjoining the ice sheet of the Pleistocene. Proc. Geologists' Assoc., vol. 48, pp. 379-395, 1937; The chronology of the Pleistocene sea levels. Ann. and Mag. Nat. Hist., ser. 2, vol. 1, pp. 389-408, 1938.

of the ice or cold intervals, separated from each other by interstadial intervals in which the climate of the world was as warm as, or warmer than, the present. The last of these ice advances was followed by a long period of amelioration of climate. Two minor episodes of cold within this time of amelioration are recorded in the Southern Rocky Mountains and named the Long Draw and the Sprague substages.

Correlation of the Sandia Cave deposits with any one of the glacial episodes of the Wisconsin would be difficult were it not that the upper breccia contains artifacts of the Folsom culture. This culture at the Lindenmeier site in Colorado has been correlated with the closing stages of the Corral Creek glacial stage or W_3. The argument on which this correlation is made has been given in the paper by Bryan and Ray already cited. If the correlation is accepted, the cave deposits of Sandia Cave represent the last major ice advance of the Wisconsin; the lower breccia with evidence of increasing wetness represents the oncoming of glaciation, the yellow ochre, the climax, and the upper breccia, the period of retreat just after the climax.

The correlation of the Corral Creek glacial stage with the Mankato and Pomeranian stages yields a date in years. Antevs[12] fixes this glacial advance as having occurred 25,000± years ago. The Folsom culture falls just after this date and the Sandia culture just before. These relations with other pertinent data are brought out in figure 9.

It should be noted that such a correlation yields a date for the Sandia culture as recorded in this one locality. As occupation of the cave and the deposition of the lower breccia began together, it appears that the cave had previously been closed. Thus there is no geologic data as to the time when the people carrying the Sandia culture arrived in New Mexico or in the continent. Furthermore the cave was presumably closed during the period of deposition of the yellow ochre, and thus the end of occupation of the area by Sandia people lies at some undefined date within the time interval of the layer of yellow ochre. With regard to the people having the Folsom culture, Sandia cave affords no critical evidence as to the time of their entrance into the continent, but presumably the people of the culture entered the local area at some time in the period of deposition of the yellow ochre. As the cave is presumed to have been closed at the end of deposition of the upper breccia, there is no geologic evidence as to the termination of the Folsom culture.

---

[12] Antevs, Ernst, The recession of the last ice sheet in New England. Amer. Geogr. Soc. Res. Ser. No. 11, 1922; The last glaciation, with special reference to the ice retreat in northeastern North America. Amer. Geogr. Soc. Res. Ser. No. 17, 1928; Late-glacial correlation and ice recession in Manitoba. Canada Geol. Surv., Mem. 168, 1931.

Whether the time interval of the yellow ochre here correlated with the climax of the Corral Creek (Mankato-Pomeranian) ice advance was a period of overlap in culture or whether the local area was deserted is at present a question in the range of anthropological probabilities. Similarly the times when these cultures began to flourish or to die out are as yet undefined locally or on a continental basis. It appears, however, pertinent to consider anew the question of migration of man into the continent, although there is as yet no conclusive evidence of a time in which he was not present.
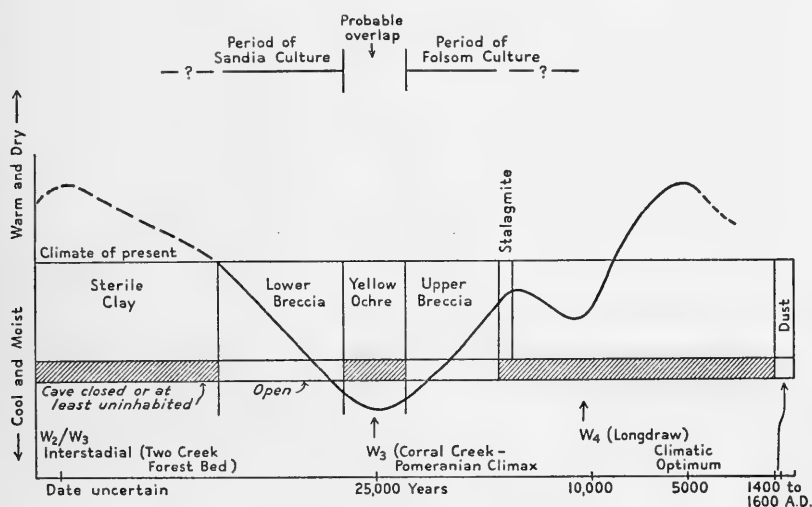

FIG. 9.—Diagram showing the relation of the deposits of Sandia Cave to the inferred climate of the late Pleistocene.

ANTIQUITY OF MAN IN NORTH AMERICA

With one possible exception [13] the Sandia culture is the only definitely established pre-Folsom culture. The antiquity of many finds has been challenged on the ground that entrance into North America must have occurred after the partial withdrawal of the ice. In its most definite form this theory is set forth by Antevs [14] who adopted from Johnston [15] the idea that the first opportunity for migration into

---

[13] Harrington, M. L., Pre-Folsom man in California. Master Key, vol. 12, No. 5, pp. 173-175, 1938. In this note Folsom points are reported in disturbed soil overlying stratified deposits containing artifacts. Full details are not yet available.

[14] Antevs, Ernst, The spread of aboriginal man to North America. Geogr. Rev., vol. 25, pp. 300-309, 1935.

[15] Johnston, W. H., Quaternary geology of North America in relation to the migration of man. *In* The American aborigines, ed. by D. Jenness, pp. 9-45, 1933.

the continent occurred when a corridor through the Canadian Great Plains was opened by the simultaneous retreat of the Cordilleran and Kewatin ice sheets. This event is connected with the geochronological sequence in Manitoba and is given a date of 15,000 years before our time or 10,000 years after the climax of the Mankato-Pomeranian ice advance (W_3). Antevs suggests the possibility that the route also was open for a time some 35,000 to 45,000 years ago, but does not imply its use by migrant peoples.

The view that the Wisconsin glacial epoch consisted of three main substages separated from each other by interstadial intervals of mild climate is relatively new. In the State of Wisconsin the Two Creeks forest bed [16] underlies Mankato till and overlies till of the next older stage and contains remains of a forest flora like that of present-day Minnesota or southern Manitoba. It records an amelioration of climate between W_2 and W_3 so great that one must suppose that little or no ice remained in Labrador. The idea that a long interval intervened between the Iowan, W_1, and the next younger Tazewell-Cary, W_2, substage is more familiar. It has long been known as the Peorian,[17] and in many localities it is supposed to be represented by loess. As now recognized by Leighton and others, the loess overlies unweathered Iowan till and cannot be much younger. It is essentially a "glacial," not an interstadial deposit. Thus near Lisbon, Iowa, where the "Peorian" loess is thick, its basal portion is unleached and calcareous. It rests on unweathered Iowan till.[18] There could have been no break in the prevailing cold climate between the retreat of the ice from this locality and the deposition of the loess. In the Farm Creek section [19] near Peoria, Ill., the "Peorian" (Tazewell or, better, Iowan) loess is blue-gray and contains bits of moss and larch twigs. It was, therefore, deposited in an environment of muskeg and scattered clumps of trees (Taiga). The climate was cold. The

[16] Wilson, L. R., The Two Creeks forest bed, Manitowoc Co., Wis. Wisconsin Acad. Sci. Trans., vol. 27, pp. 31-46, 1932.

[17] Note that the loess which lies between the Illinoisan loess and the Tazewell till in the Farm Creek section is now referred to as the Iowan loess. Peorian is applied to the usually indistinguishable combination of Iowan and Tazewell loess which overlies the area south of the Tazewell moraines. Thornbury, W. D., Weathered zones and glacial chronology in southern Indiana. Journ. Geol., vol. 48, pp. 449-475, 1940.

[18] Alden, W. C., and Leighton, M. M., The Iowan Drift: a review of the evidences of the Iowan stage of glaciation. Iowa Geol. Surv., vol. 26, pp. 156-157, 1915.

[19] Leighton, M. M., A notable type Pleistocene section: the Farm Creek exposure near Peoria, Ill. Journ. Geol., vol. 34, pp. 167-174, 1926.

overlying Shelbyville (Tazewell) till represents a new advance of the ice which sheared off the top of the loess. However, at the west end of the section a humus-bearing soil of infantile development is preserved.[20] West of Mackinaw, Ill., also, the loess has an infant soil development and is overlain by the Tazewell till. The Peorian interstadial is represented by these infantile soils, which reflect a milder climate. The length of the interval is attested not by these soils but by the relatively large amount of erosion that occurred between the deposition of the Iowan and Tazewell tills.[21] It should be kept in mind that many eminent students of the question have long held the view that the post-Iowan was a true interglacial stage and therefore had a longer and milder climate than here assumed.[22]

The evidence that an amelioration of climate occurred in North America in the W_2/W_3 interval thus is not wholly conclusive. If, however, on the basis of the complete European evidence this partial American evidence be accepted, and due weight is given to the Two Creeks forest bed, an important conclusion follows. The existence of these mild interstadial intervals in the Wisconsin implies that the route of migration through the Canadian plains was open twice during the Wisconsin. It would have been possible for the Sandia people to have entered the continent in the last one of these interstadials, W_2/W_3, when the Two Creeks forest bed was laid down under mild climatic conditions. They would then have had a relatively long period of time to reach New Mexico and to become well-established and perhaps have developed unique traits by the onset of the ensuing glaciation. This substage (W_3) was sufficiently well-advanced when the record begins in Sandia Cave, so that drip from the roof had begun. Whether the Folsom people also entered in this interstadial or whether the descendents of the Sandia people or some unknown people of the same antiquity developed the Folsom culture is an issue on which the geologic evidence sheds no light.

Estimates of the date in years of Pleistocene events previous to the Mankato-Pomeranian (W_3) substage are subject to large errors. Kay[23] has made an estimate of the age of Iowan and other drifts by consideration of the depth to which they have been leached of

[20] Leighton, M. M., The Peorian loess and the classification of the glacial drift sheets of the Mississippi Valley. Journ. Geol., vol. 39, pp. 48-50, 1931.

[21] Alden, W. C., and Leighton, M. M., op. cit.

[22] Leverett, Frank, The place of the Iowan Drift. Journ. Geol., vol. 47, pp. 398-407, 1939, and earlier papers.

[23] Kay, G. F., Classification and duration of the Pleistocene period. Bull. Geol. Soc. Amer., vol. 42, pp. 425-466, 1931.

calcium carbonate. This method is applicable to the drifts of the Middle West which have a high content of limestone pebbles. The average depth of leaching in Iowa in the Mankato (Des Moines lobe) is 2.5 feet. This material has been exposed to weathering for 25,000 years, or since the beginning of retreat of the ice of this sub-stage, W_3. The rate of leaching is a tenth of a foot for each 1,000 years. Using this factor and extensive data on leaching, Kay has attained a date for the Iowan and also for the second interglacial. Thornbury in the paper previously cited has applied the same method to the Tazewell, W_2, substage in Indiana. These estimates are shown in table 2:

TABLE 2.—*Elapsed time to glacial stages and substages*

Substage or stage	Average depth of leaching in feet	Elapsed time in years
Mankato till	2.5	25,000
Tazewell till [a]	4.5	45,000
Iowan till	5.5	55,000
Sangamon (gravel, etc.)..............	12.0	120,000

[a] Thornbury's data from Indiana.

These estimates are based on two assumptions: that the rate of solution has been uniform; and that there has been no surface loss of material, or, if there has been, that this loss has been at a uniform rate. Neither of these assumptions can be so. When the ice began to melt away from its most advanced position in the Mankato, the climate must still have been cold, and it did not much ameliorate for a considerable period. We have in Europe an excellent record of the climate during the synchronous retreat of the ice from the moraine in the south shore of the Baltic across Sweden and Finland. It required about 15,000 years for the ice to reach the Fennoscandian moraine and during this time the climate was near-Arctic in type and the *Dryas* or tundra vegetation flourished. There was then a slight readvance of the ice occupying a period of 670 years.[24] Warmer conditions did not begin until about the beginning of the Post-glacial in the European sense or 16,000 years after the beginning of retreat. During this cold period there was some solifluction and removal of the surface of glacially deposited material. Doubtless also some solution occurred. One must conclude that the bulk of the solution of limestone in the exposed glacial deposits has occurred within the past 9,000 years.

[24] Sauramo, Matti, The Quaternary geology of Finland. Bull. Comm. Geol. Finlande, No. 86, pp. 1-110, 1928.

If we consider the areas of the farthest advance of the Pomeranian or Mankato ice to the south, these areas must have had a near-Arctic climate during a large part of the advance, the climax, and the retreat of the ice. Not only was solution at a minimum, but removal of surface material by solifluction must have occurred. Thus part of the material leached during the mild climate of the previous inter-stadial must have been removed. On very flat undrained areas, such as those postulated in the great areas of the Illinois drift, removal may have been at a minimum.
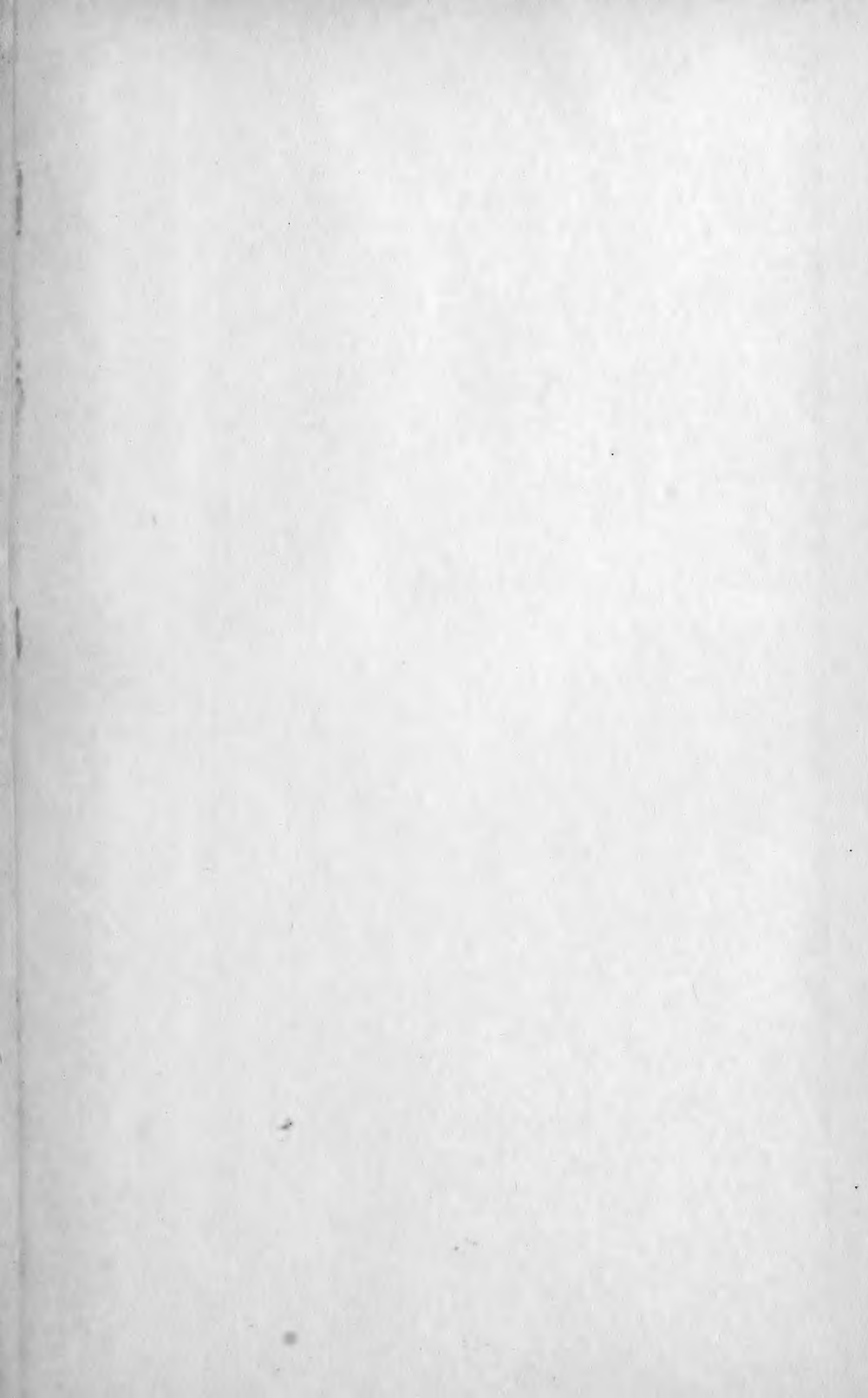
INFERENCES FROM THE INTERSTADIAL ENTRANCE OF MAN

The evidence here presented that man existed in the early part of W_3 and that his probable entrance occurred in the interstadial W_2/W_3 illuminates other archeological finds. Of these one of the most important is the skeleton known as Minnesota man.[25] These bones, which are those of a young girl, were found with two shell ornaments and a bone knife in the silts deposited in a glacial lake in western Minnesota. This lake was a small water body which existed while an ice mass filled the Red River valley (basin of Lake Agassiz) and while the Big Stone moraine was being built. The water was ponded against the hills of the Altamont-Gary system of moraines, previously built by the same ice lobe. The controversy regarding the antiquity of these bones has made it plain that the objectors are not solely con-cerned with local details bearing on the provenance of the bones. They are appalled at the relatively great antiquity which must be assumed. The silts in which the skeleton was found were deposited in a lake contemporaneous with the Big Stone moraine. As this moraine formed after the climax of the Mankato substage, it must be of the order of 18,000 to 20,000 years old.[26] If, however, the Sandia people entered North America in the pre-Mankato interstadial W_2/W_3 there seems no good reason to suppose that the ancestors of the Minnesota girl may not have entered also. On such a supposition ample time would be available to develop several unlike cultures by the time of the begin-ning of retreat of the Mankato ice. Thus the disparity between the cultural objects found with the Minnesota girl and the Folsom and Sandia cultures might be explained, although their similarity to recent material still presents a problem. The marine shell found as an orna-ment with the Minnesota girl without doubt came from the Gulf

---

[25] Jenks, A. E., Pleistocene man in Minnesota, 197 pp. Univ. Minnesota Press, 1936.

[26] As estimated by Leverett and Antevs. See Jenks, op. cit.

Coast, but if settlement had been so long established, it might easily have been obtained through well-established trade between Minnesota and the Gulf.

The Folsom culture of the original site and of the Lindenmeier site are very similar. There are, however, other fluted points, widespread in their distribution, which show considerable typological variation. The anthropological explanation of this differentiation is facilitated by an enlargement of the time interval during which man has inhabited the continent. Similarly the complex differentiation of cultures represented by the wide array of cultural objects now included in "Yuma" is easier of explanation in view of the increased time allowed for such differentiation. Limitations on the time after the Corral Creek climax during which the Folsom culture flourished await the study of stratified Yuma sites and their successful geologic dating.